BOFIT Discussion Papers
25 • 2011

Yin-Wong Cheung and Eiji Fujii

# Exchange rate misalignment estimates – Sources of differences

Bank of Finland, BOFIT
Institute for Economies in Transition

BOFIT Discussion Papers
Editor-in-Chief Laura Solanko

BOFIT Discussion Papers 25/2011
26.9.2011

Yin-Wong Cheung and Eiji Fujii: Exchange rate misalignment estimates – Sources of differences

ISBN 978-952- 462-720-7
ISSN 1456-5889
(online)



Suomen Pankki
Helsinki 2011

# Contents

Yin-Wong Cheung and Eiji Fujii

# Exchange rate misalignment estimates – Sources of differences

## Abstract

We study the differences in currency misalignment estimates obtained from alternative datasets derived from two International Comparison Program (ICP) surveys. A decomposition exercise reveals that the year 2005 misalignment estimates are substantially affected by the ICP price revision. Further, we find that differences in misalignment estimates are systematically affected by a country's participation status in the ICP survey and its data quality – a finding that casts doubt on the economic and policy relevance of these misalignment estimates. The patterns of changes in estimated degrees of misalignment across individual countries, as exemplified by the BRIC economies, are highly variable.

JEL Classifications: F31, F41, E01, C31

Keywords: Penn effect regression, data revision, PPP-based data, measurement factors, economic factors

We thank Michael Funke, Eric Girardin, Iikka Korhonen, Honglin Wang, Shang-Jin Wei, Matthew Yiu, and participants of the BOFIT Workshop on China's Monetary and Exchange Rate Policy and the HKIMR seminar for their comments and suggestions. Cheung and Fujii gratefully acknowledge the financial support of, respectively, the faculty research funds of the University of California, Santa Cruz and of the JSPS' Grant-in-Aid for Scientific Research (#14530039).

Corresponding addresses: Yin-Wong Cheung – Economics Department, University of California, Santa Cruz, CA 9506,USA. Email: cheung@ucsc.edu. Department of Economic and Finance, City University of Hong Kong, Hong Kong. Email: yicheung@cityu.edu.hk Eiji Fujii – School of Economics, Kwansei Gakuin University, 1-155 Uegahara Ichiban-cho, N shinomiya, Hyogo 662-8501, Japan. Tel: +81 798 54 7257. Fax: +81 798 51 0944. Email: efujii@kwansei.ac.jp.

Yin-Wong Cheung and Eiji Fujii

# Exchange rate misalignment estimates – Sources of differences

## Tiivistelmä

Tutkimuksessa tarkastellaan valuuttakurssien epätasapainoja kolmen eri tilastoaineiston avulla. Kaikki aineistot perustuvat International Comparison Programin (ICP) arvioihin pohjautuviin tietoihin maailman maiden hintatasoista ja ostovoimapariteeteista. Tutkimuksessa osoitetaan että arviot valuuttakurssien epätasapainosta vuonna 2005 riippuvat merkittävästi siitä, mitä aineistoa analyysin pohjana käytetään. ICP-ohjelman uudet, tarkistetut arviot vertailukelpoisista hintatasoista vuonna 2005 antavat hyvin erilaisia tuloksia valuuttakurssien epätasapainoista kuin aikaisemmat arviot. Lisäksi tulokset riippuvat systemaattisesti siitä, osallistuuko arvioitava maa ICP-ohjelman haastattelututkimukseen, sekä maan tilastojen laadusta. Tämän tuloksen pohjalta on syytä kysyä kuinka suuri taloudellinen ja poliittinen painoarvo valuuttakurssien epätasapainon estimaateille tulisi antaa. Estimaattien muutokset eri maiden välillä ovat suuria ja syyt vaihtelevia, mistä esimerkkinä käytetään BRIC-maiden tuloksia.

JEL: F31, F41, E01, D31
Asiasanat: Penn regressio, tilastoaineiston päivitykset, ostovoimapariteetti, mittausvirhe

# 1 Introduction

Exchange rate misalignment is commonly perceived to be the culprit of various domestic and global economic ills. A recent example is the assertion that exchange rate misalignment has led to severe global imbalances, threatened global economic stability, caused the 2008-9 global financial crisis, and impeded the recovery from the crisis.

Indeed, the contentious debate on trade imbalances between China and the US usually focuses on the valuation of the Chinese currency the renminbi (RMB). A shorthand version of the typical view is that China, by artificially depressing its currency's value, builds up surpluses and creates huge global imbalances. Thus, the remedy is for China to let its currency appreciate and thus rectify the global imbalances and restore global stability.

One overarching question underlying debate is how to assess the extent of exchange rate misalignment. A credible estimate of the level of misalignment would gauge the severity of the problem and facilitate the design of an appropriate policy response. An imprecise misalignment estimate, on the other hand, would make it difficult to appraise its importance and policy relevance. The current study, therefore, focuses on assessing the level of exchange rate misalignment and identifying possible sources of differences in misalignment estimates.

In assessing currency misalignment, the internationally comparable data derived from surveys conducted by the International Comparison Program (ICP) play a unique role. Because of their comparability properties, the ICP-based data give us some "consistent" information that will facilitate cross-country comparison of purchasing powers and real exchange rates. In considering China-US imbalance issues, for instance, Frankel (2006), Cheung, Chinn and Fujii (2007) and Coudert and Couharde (2007) used these data to assess the degree of RMB undervaluation.

There are numerous studies reporting that the RMB is (substantially) undervalued as noted by, for example, Cheung, Chinn and Fujii (2010a) and Korhonen and Ritola (2011). Nevertheless, these estimates could be quite sensitive to the choices of sample period, model specification, and parameter assumptions (Cheung, Chinn and Fujii, 2010b; Dunaway, Leigh and Li, 2009; Hu and Chen, 2010; Wang and Hu, 2010). In addition, Cheung, Chinn and Fujii (2010b) illustrate that the latest revision of the ICP-based internationally comparable data has striking implications for evaluating currency misalignment.

Since it was established in 1968, the ICP has conducted periodic surveys on national prices. The survey results are used to produce internationally comparable price indices and national output data. Despite the effort to make national price data comparable, it remains a daunting task to aggregate and compare prices of vastly dissimilar products from countries of different economic characteristics and over time. The latest round of ICP survey was conducted in 2005, and the results were released in 2008. The new survey results lead to some large and surprising data revisions. Two often cited examples are China and India. According to the 2005 round survey data, their 2005 *per capita* GDPs are, respectively, 39% and 38% smaller than previously estimated. Some countries, indeed, have their 2005 *per capita* GDPs revised up or down by 50% or more (World Bank, 2008a).

These drastic data revisions raise concerns about the robustness of empirical results derived from previous ICP data vintages. Cheung, Chinn and Fujii (2009, 2010b) discuss the implications of the 2005 ICP round for assessing currency misalignment.[1] Specifically, they showed that the Chinese currency's misalignment estimate obtained from the revised data is quite different from that obtained in previous studies – the new undervaluation estimate for 2004 turns out to be around 18%, which is only about one-third of the "old" estimate of 53%. Even if one allows for the possibility that the 2005 ICP survey overstated China's national price level, the reduction in misalignment estimate is substantial.[2] It is natural to ask: What are the factors affecting the change in misalignment estimates?

The current paper studies the currency misalignment estimates obtained from a few alternative datasets that are based on the ICP survey data. Are there systematic patterns in the differences in estimated degrees of misalignment? What are the potential determinants of these differences? Answers to these questions could help us to evaluate the relevance of currency misalignment estimates for, say, policy discussions.

Besides documenting their changes, we examine the components of the differences of misalignment estimates and the factors affecting these differences. In anticipation

[1] Some recent studies have showed that the data revision could substantially alter, for example, growth rate estimates, the negative growth volatility effect, growth determinants, poverty measures, and inequality assessment; see, for example, Ciccone and Jarocinski (2010), Johnson, Papageorgiou, and Subramanian (2009), Ponomareva and Katayama (2010), Chen and Ravallion, (2010a, 2010b), and Milanovic (2009).
[2] Deaton and Heston (2010) suggested that China's national price level – the PPP GDP deflator – could be overstated by 10%. According to Chen and Ravallion (2010b), the PPP consumption deflator could be overstated by about 10%.

of the results, misalignment estimates could be quite variable across different vintages of ICP-based data.

We decompose revisions in misalignment estimates into changes in real exchange rate data and changes in estimated equilibrium exchange rates. The relative contributions of these two components vary across different country groups.

One factor that could affect data revision is a country's participation status in the ICP survey. For instance, China and India participated in the 2005 ICP price survey but not in the previous 1993 round. Prior to the release of the 2005 benchmark information, price data for these two countries were estimated and projected using partial or incomplete information. These guesstimates could systematically overstate or understate the degree of misalignment.

Data quality is another potentially important factor.[3] World Bank (2008a) shows that large revisions from the 2005 round survey are usually associated with low income countries. These countries tend to provide low quality economic data, which are used to estimate and project their ICP-based data beyond the survey year. When a new survey is conducted, countries with initially poor quality data are more likely to experience a substantial revision.

Both the participation status and the data quality are related to measurement issues. If the data revision and, hence, the change in a misalignment estimate is attributable to these measurement factors, then the misalignment estimates themselves may not be closely related to the deviation from the equilibrium value predicted by the relevant exchange rate theory. That is, the measured misalignment would not provide a good gauge of the actual deviation from equilibrium and, thus, may not be useful for devising the appropriate remedial policy.

What are the economic factors that could affect the currency misalignment estimates? A widely used approach to assessing currency misalignment is the Penn effect approach, which estimates equilibrium exchange rates by exploiting an empirically robust relationship between national price levels and *per capita* income levels. Deviations from this relationship are interpreted as measures of real exchange rate misalignment (Balassa, 1964). Frankel (2006), Cheung, Chinn and Fujii (2007), and Coudert and Couharde (2007),

[3] Data quality can have significant ramifications for various empirical analyses. See, for instance, Cheung and Chinn (1996) for implications for studying output dynamics, and Dawson, DeJuan, Seater and Stephenson (2001) for implications for estimating the income volatility effect on growth.

for example, adopt this approach to provide RMB misalignment estimates. Against the backdrop of the Penn effect regression, we consider the initial level of output, output growth, openness and inflation as the economic factors that could potentially influence misalignment estimates.

Given the lack of consensus regarding what constitutes equilibrium exchange rates, the Penn effect approach and ICP-based data may not be unanimous choices for assessing currency misalignment. Nevertheless, by drawing upon the widely used method and data, we anticipate that our exercise will shed some light on the difficulty of evaluating currency misalignment and its policy implications. For instance, if the revision is mainly driven by changes in real exchange rate data (due to the change in survey method) or the measurement-related factor, then the empirically estimated misalignment measure may bear limited economic information about the actual level of misalignment based on theoretical considerations and, thus, may not be very helpful in devising the corresponding policy response.

# 2 Preliminaries

Since the 1970s, the ICP has conducted surveys on national prices at irregular intervals.[4] The survey results are used to produce internationally comparable price indices, which are labeled purchasing power parities (PPPs). Using, say, the US as the numeraire country, a country's national price level is given by its PPP normalized by its US dollar exchange rate. The PPP-based gross domestic product (GDP) – which allows international comparison of real incomes and economic sizes – is the GDP in local currency units normalized by its national price level.[5]

The *Penn World Table* (*PWT*, http://pwt.econ.upenn.edu/) and the *World Development Indicators* (*WDI*, http://data.worldbank.org/data-catalog/world-development-indicators) are the two main data sources for these internationally comparable price and output measures. These data are commonly used in both academic and policy related cross-

[4] The ICP conducted price surveys in 1970, 1973, 1975, 1980, 1985, 1993 and 2005; which covered, respectively, 10, 16, 34, 60, 64, 117 and 146 countries.

[5] The terms PPP and national price level are potentially confusing for those who are not familiar with the ICP data. In this context, the PPP is a local currency price measure and the national price level is a relative price, which is equivalent to the inverse of the real exchange rate. We will use these terms interchangeably in the text.

country comparison exercises. More recently, PPP-based GDP data were included in the process of assessing quota subscriptions of International Monetary Fund member countries (IMF, 2011; Silver 2010).

The comparability of these ICP-based data greatly facilitates the assessment of economic performance across countries. The usefulness of these data, however, is impeded by the evolution of the ICP survey itself. Specifically, the ICP has modified its survey methodology, country coverage, and product sample from one survey to another. These modifications make comparing PPPs of different vintages a non-trivial exercise. The PPP and national price level estimates from a new survey could be quite different from those projected based on information obtained from previous surveys.

The latest round of ICP survey, conducted in 2005, incorporated a few major changes in survey design, and data collection and processing methods (World Bank, 2008a, b,c). The resulting new PPP estimates represent some substantial data revisions.

## 2.1 Data

In the current study, we focus on the year 2005 currency misalignment estimates derived from three versions of PPP-based real exchange rate and output data. The first dataset (*WDI* 2007) contains year 2005 data downloaded from WDI in July 2007. The second dataset (*WDI* 2008) was downloaded in April 2008. The third (*PWT* 6.3) was extracted from the *PWT* version 6.3 database.[6] The two WDI datasets give the year 2005 PPP-based data before and after the incorporation of the 2005 ICP survey results. The *PWT* version 6.3 is derived from the pre-2005 survey information. At the time of writing, the *PWT* version 7.0 that includes the data from the latest 2005 ICP round is under preparation and not yet available.

The two WDI datasets provide the primary information to evaluate the magnitude of and the factors affecting misalignment revision induced by information from the latest 2005 ICP round. Results from analyzing these data allow us to infer the reliability and economic interpretations of misalignment estimates derived from these internationally comparable ICP-based data.

[6] *PWT* version 6.3 provides two China series. However, for the benchmark year 2005, there is no difference between the two versions of price and *per capita* GDP data.

The PWT data are included to offer an alternative view of the effect of the 2005 round revision. Both the *PWT* 6.3 and *WDI 2007* datasets were based on information from the pre-2005 ICP survey. The main difference between them is the difference in statistical procedures for constructing their PPP-based national price and output series. For instance, PWT uses the GK method to compute the aggregate price index and WDI uses the GEKS method.[7] Deaton and Heston (2010) offer an excellent overview of these aggregation formulations and other issues of constructing PPPs. The differences between *WDI 2007* and *WDI 2008* and between *WDI 2007* and *PWT 6.3* databases could thus provide alternative perspectives on the new information embedded in the 2005 ICP survey.

## 2.2 Penn *Effect*

The basic Penn effect regression equation is given by

$$r_i = \beta_0 + \beta_1 y_i + u_i \qquad (1)$$

where $r_i$ and $y_i$ are, respectively, country *i*'s national price level and real *per capita* income in logs and relative to the corresponding US variables. The national price level indeed is the reciprocal of the PPP-based real exchange rate - an increase in $r_i$ means an appreciation of the currency. Henceforth, we call $r_i$ the real exchange rate for brevity.

Apparently coined by Samuelson (1994), the Penn effect refers to the robust empirical positive association between national price levels and real per capita incomes documented by a series of Penn studies (Kravis and Lipsey, 1983, 1987; Kravis, Heston and Summers, 1978; Summers and Heston, 1991). That is, a high income country tends to have a high real exchange rate. The positive empirical relationship can be explained by the difference in productivities between the tradable and nontradable sectors (Balassa 1964; Samuelson 1964) or by the factor-endowment-based approach developed by Bhagwati (1984) and Kravis and Lipsey (1983).

The Penn effect framework has been adopted in the recent debate on RMB misalignment. The inference of currency misalignment based on equation (1) hinges upon the robust positive Penn effect and the implicit assumption that real exchange rates relative to

[7] The GK method is due to Geary (1958) and Khamis (1972), and the GEKS method to Gini(1924), Eltetö and Köves (1964), and Szulc (1964). See Deaton and Heston (2010) for details.

the US may be overvalued or undervalued, but they are at the equilibrium level on average. To ensure data compatibility, the empirical analysis is typically conducted with PPP-based real exchange rates and GDP measures.

The estimated equilibrium real exchange rate according to the Penn effect approach is given by $\hat{\beta}_0 + \hat{\beta}_1 y_i$, where "^" indicates an estimate. The estimated degree of misalignment is given by the estimated residual $\hat{u}_i$, a positive value implying overvaluation and a negative value undervaluation.

The results of estimating (1) are presented in Panel A, Table 1. To facilitate comparison between the three datasets, our country sample includes 154 countries for which both real *per capita* income and real exchange rate data are available for 2005. The data sources and country sample are detailed in the Appendix. Some remarks are in order.

For the Penn effect, the estimate $\hat{\beta}_1$ affirms the presence of a significantly positive empirical relationship between national income and real exchange rate level, albeit with varying magnitudes in all three datasets. The *WDI* 2008 vintage that includes the 2005 ICP round information has the smallest Penn effect estimate $\hat{\beta}_1$. The decline in the Penn effect is also observed by Cheung, Chinn and Fujii (2010b). The $\hat{\beta}_1$-estimates from *WDI* 2007 and *PWT* 6.3 are quite similar to each other. Recall that both *WDI* 2007 and *PWT* 6.3 data are based on the 1993 ICP survey, though they employ different index construction and updating methods. Apparently, the commonality of the ICP survey dominates the estimation of the Penn effect.

The estimated degrees of exchange rate misalignment of the BRIC countries; namely Brazil, Russia, India and China are used to illustrate a few country-specific results (Panel B, Table 1).[8] The misalignment estimates from the three different datasets exhibit different patterns and lead to a few interesting observations.

The Chinese RMB misalignment estimates from both *WDI* 2007 and *PWT* 6.3 are largely in line with those reported in, for example, Frankel (2006) and Cheung, Chinn and Fujii (2007). The estimates indicate a large degree of undervaluation, from 50.56% (*PWT* 6.3) to 64.43% (*WDI* 2007). The *WDI* 2008 data that included the latest ICP survey information, however, imply a strikingly different misalignment estimate – the RMB is undervalued by 14.38%, which is less than one quarter of the estimate from *WDI* 2007. The

[8] The misalignment estimation results for other countries are given in Table A1 of Appendix C.

dramatic decrease echoes the findings of Cheung, Chinn and Fujii (2010b). The ICP data revision has a much larger impact on misalignment estimates than the use of different index construction methods.

The Indian Rupee's misalignment estimates show a pattern similar to that of the RMB. Its undervaluation estimate from *WDI* 2008 is about 40% of those from *WDI* 2007 and *PWT* 6.3. For the Brazilian real and Russian ruble, the use of *WDI* 2008 data does not reduce the degrees of undervaluation. Indeed, the 2005 ICP survey data suggest that these two currencies, especially the Russian ruble, are more undervalued than previous estimates suggest.

The BRIC countries are fast growing developing countries that are becoming increasingly integrated into the global economy. Why are the revisions of misalignment estimates so different across the BRIC countries? One possibly important distinction is whether or not they participated in the ICP survey. As noted in the introduction, China and India participated in the 2005 ICP survey but not in the earlier 1993 round. Thus, before the 2005 ICP survey results are available, the 2005 PPP-based data for these two countries were constructed from incomplete and dated information. Brazil and Russia, on the other hand, participated in the 1993 survey and thus are among the group of 1993 benchmark countries. On this account, their 2005 PPP-based data in *WDI* 2007 are projected from the earlier 1993 ICP survey.

To shed some light on the difference between the 1993 benchmark and non-benchmark countries, Panel C of Table 1 presents the averages of (absolute) misalignment estimates for those that participated in the 1993 ICP survey and those that did not. Comparing *WDI* 2007 and *WDI* 2008, the average misalignment estimates of the benchmark and non-benchmark groups are quite similar in magnitude but of opposite signs. The mean absolute averages provided in square brackets from *WDI* 2008 are about one-third less than the corresponding ones from *WDI* 2007. The average misalignment estimates from *PWT* 6.3 are smaller than those from the other two datasets, while the absolute averages are comparable to those from *WDI* 2007.

Figure 1 presents the misalignment estimates. The countries are ordered according to their misalignment estimates – from the lowest (i.e. the most undervalued) to the highest (i.e. the most overvalued) – derived from the *WDI* 2007 Penn effect regression. The differences in the 2005 misalignment estimates appear to be substantial, and the patterns of the three misalignment estimate series differ greatly. Indeed, the estimated correlation coefficient is 0.49 for *WDI* 2007 versus *WDI* 2008 misalignment estimate, 0.54 for *WDI* 2007 versus *PWT* 6.3, and 0.52 for *WDI* 2008 versus *PWT* 6.3. The relatively low correlation between misalignment estimates from *WDI* 2007 and *WDI* 2008 may not be too surprising given the substantial 2005 ICP survey update. It is a bit unexpected to observe the low correlation between the misalignment estimates from *WDI* 2007 and *PWT* 6.3, which are both based on the same 1993 ICP survey information. In the next section, we investigate the sources of the differences between these 2005 misalignment estimates.

# 3 Sources of Differences

Consider the Penn effect regressions based on two different data vintages:

$$r_{i.v1} = \beta_{0,v1} + \beta_{1,v1} y_{i,v1} + u_{i,v1}$$

and

$$r_{i.v2} = \beta_{0,v2} + \beta_{1,v2} y_{i,v2} + u_{i,v2}$$

where $v1$ denotes the *WDI* 2007 dataset and $v2$ denotes either the *WDI* 2008 or the *PWT* 6.3 dataset. The difference in misalignment estimates is defined by $\Delta\hat{u}_{i,v2,v1} \equiv (\hat{u}_{i,v2} - \hat{u}_{i,v1})$. For brevity, we call $\Delta\hat{u}_{i,v2,v1}$ the WDI revision when $v2 \equiv$ *WDI* 2008 and the PWT-WDI differential when $v2 \equiv$ *PWT* 6.3.

The series of WDI revision and PWT-WDI differential are plotted in Figure 2. The countries are arranged according to size of WDI revision, from smallest to largest. Visually, the variations of these two series are quite dissimilar; the estimated correlation between the two series is 0.51.

The change in misalignment estimates could be expressed as

$$\Delta\hat{u}_{i,v2,v1} = r_{i.v2} - r_{i.v1} - (\hat{r}_{i.v2} - \hat{r}_{i.v1}) \equiv \Delta r_{i,v2,v1} - \Delta\hat{r}_{i,v2,v1} . \quad (2)$$

That is, the change in misalignment estimate is attributed to a change in data on real exchange rates or a change in estimated equilibrium rates. When the change in estimated misalignment is positive (negative), $\hat{u}_{i,v2}$ represents an estimated level of undervaluation that is smaller (larger) than that implied by $\hat{u}_{i,v1}$.

The change in estimated equilibrium rates could be further written as

$$\Delta\hat{r}_{i,v2,v1} = [(\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1}y_{i,v2}) - (\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1}y_{i,v1})] + [(\hat{\beta}_{0,v2} + \hat{\beta}_{1,v2}y_{i,v2}) - (\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1}y_{i,v2})] \quad (3)$$

where $[(\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1}y_{i,v2}) - (\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1}y_{i,v1})]$ represents the effect of the change in income, assuming the Penn effect regression coefficient estimates do not change and $[(\hat{\beta}_{0,v2} + \hat{\beta}_{1,v2}y_{i,v2}) - (\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1}y_{i,v2})]$ represents the effect of the change in the Penn coefficient estimates, assuming income is at the v2 level.

## 3.1 Decomposition Results

The results of decomposing misalignment estimate revisions are presented in Table 2. For the indicated country groups, Panel A and Panel B present the averages of changes in misalignment estimates ($\Delta\hat{u}_{i,v2,v1}$'s), their components of changes in data on real exchange rates ($\Delta r_{i,v2,v1}$'s) and in estimated equilibrium values ($\Delta\hat{r}_{i,v2,v1}$'s). The averages of the components of change in estimated equilibrium values are given in the last two columns. Panel A gives the results pertaining to WDI revisions; that is the change in misalignment estimates between the *WDI* 2008 and *WDI* 2007 datasets. In addition to the entire country sample, we examine the decomposition for 1993 benchmark and non-benchmark countries and for countries with positive and negative misalignment estimate revisions.

In Panel A, the average changes in the estimated equilibrium values ($-\Delta\hat{r}_{i,v2,v1}$'s) are negative and, thus, have a negative impact on the misalignment estimates for the selected country groups. They all lead to a larger estimated level of undervaluation. These changes in estimated equilibrium values are dominated by their respective negative changes in the Penn effect component presented in the last column.

For the entire country sample, the sum of changes in misalignment estimates is zero by construction. Thus, the total changes in data on real exchange rate and in estimated equilibrium rate are of the same magnitude but opposite in sign. The ICP survey results, however, have differential implications for revisions experienced by different country groups. The revision in misalignment estimates, $\Delta\hat{u}_{i,v2,v1}$, of the non-benchmark country group is of much larger magnitude than that of the benchmark country group. It is more heavily influenced by the change in data on real exchange rates than by the change in estimated equilibrium values. In other words, countries not participating in the ICP 1993 survey are more likely to experience a large real exchange rate revision, which in turn induces a substantial revision in the estimated level of misalignment.

The countries for which there are positive misalignment estimate revisions are on average affected more heavily by changes in data on real exchange rates than those with negative revisions. These countries also tend to have more substantial changes in the income component than those with negative misalignment estimate revisions.

The decomposition of PWT-WDI differentials is presented in Panel B of Table 2. In contrast to the results in Panel A, the averages of estimated equilibrium value components are positive for both the benchmark and non-benchmark country groups and hence for the total sample. Thus, compared with the WDI 2007 data, the estimated equilibrium value component tends to contribute to a smaller estimated degree of undervaluation for the *PWT* 6.3 data. The decomposition results in the last two columns reveal another contrasting observation. Unlike the WDI-revision case in Panel A, the differences in PWT-WDI estimated equilibrium values tend to have smaller income components than Penn effect components. The differences between these two components, however, are usually smaller than those in Panel A.

The difference in misalignment estimates appears larger (in absolute terms) for non-benchmark than for benchmark countries. On average, the *PWT* 6.3 results indicate that non-benchmark countries have smaller degrees of undervaluation than those from the *WDI* 2007 dataset. The opposite is true for benchmark countries, albeit the differences are smaller in magnitude.

For 89 of the 154 countries, the difference in misalignment estimates is positive; indicating that the *PWT* 6.3 data yield a smaller estimated level of undervaluation than the *WDI* 2007 data. For either the countries with positive revisions or those with negative revisions, $|\Delta r_{i,v2,v1}|$ is always larger than $|\Delta\hat{r}_{i,v2,v1}|$. That is, the difference in PPP-based exchange rates contributes more (in absolute terms) to the difference in misalignment estimates than does the difference in estimated equilibrium rates.

Comparing decomposition results in Panels A and B, we observe that, while the WDI-revision and PWT-WDI differential display a few similarities, they exhibit some discernable differences. It appears that the averages of the WDI-revision are usually larger (in magnitude) than the averages of the PWT-WDI difference.

The decomposition results pertaining to the four BRIC countries are presented in Panel C and Figure 3. For China and India, the two 1993 non-benchmark BRIC countries, the reduction in undervaluation estimates is substantial, between 60% and 78%. Most of the reduction comes from the upward revision of their PPP real exchange rates. Indeed, the revision in Chinese data on real exchange rate is almost the same as the revision in its misalignment estimate (0.506 vs 0.500); the change in its estimated equilibrium rate has little impact on misalignment revision. This is because the substantial downward revision of China's income is essentially offset by the change in the Penn effect (last two columns of Panel C and Figure 3A).

The decrease in Indian rupee undervaluation is smaller than the change in its real exchange rate data. The change in the rupee equilibrium rate estimates, which is dominated by the change in Penn effect, offsets about 22% of the effect of real exchange rate revision on its misalignment estimate.

Brazil's and Russia's currency misalignment estimates are less influenced by the revision in PPP real exchange rates following the latest ICP survey. As noted earlier, these two 1993 benchmark countries see an increase, instead of a reduction, in the extent of their undervaluation estimates. The revisions in their equilibrium exchange rate estimates, which are heavily influenced by the change in the Penn effect, account for a large (absolute) share of the changes in misalignment estimates (Panel C and Figure 3A). The anecdotal evidence so far suggests that the currency misalignment estimates of the two benchmark BRIC countries and the two non-benchmark BRIC countries have been differently affected by the latest ICP survey results.

With the exception of Brazil, the magnitudes of misalignment estimate revision are smaller for the PWT-WDI differential than for the WDI revision (Panel C.i and C.ii). Further, the magnitudes of changes in data on real exchange rates, in estimated equilibrium rates, and in the components of change in estimated equilibrium rates are smaller for the PWT-WDI differential than for the WDI revision. Thus, while the different methods employed by the PWT and WDI affect the currency misalignment assessment for these BRIC countries, the effect is less serious than that for the 2005 ICP survey update.

## 3.2 Regression Analysis I: Measurement Related Factors

In this subsection, we use the regression method to identify the determinants of currency misalignment revision. First, we consider two measurement-related factors: whether the country is a benchmark country in the 1993 ICP survey and the quality of the country's data. Specifically, we consider

$$\Delta\hat{u}^{+}_{i,v2,v1} = \alpha_0 + \alpha_1 D_{i,nBM} + \alpha_2 Q_i + \varepsilon_i \,, \tag{4a}$$

and

$$\Delta\hat{u}^{-}_{i,v2,v1} = \alpha_0 + \alpha_1 D_{i,nBM} + \alpha_2 Q_i + \varepsilon_i \,. \tag{4b}$$

$\Delta\hat{u}^{+}_{i,v2,v1}$ and $\Delta\hat{u}^{-}_{i,v2,v1}$ are, respectively, positive and negative changes in misalignment estimates. $D_{i,nBM}$ is a dummy variable that takes the value one when country *i* is not a benchmark country in the 1993 ICP survey and of zero otherwise. $Q_i$ is the data quality dummy variable, equal to one if country *i*'s data quality rating is C, C-, D+, or D or to zero if data quality rating is A, A-, B+, B, or B-. The data quality information is from Summers and Heston (1991). The sample correlation between $D_{i,nBM}$ and $Q_i$ is .247. The regression error term is given by $\varepsilon_i$.

The decision to examine separately positive and negative changes in misalignment estimates is motivated by the decomposition results in Table 2, which indicate that $\Delta\hat{u}^{+}_{i,v2,v1}$ and $\Delta\hat{u}^{-}_{i,v2,v1}$ are likely to have different properties. Indeed, in the pilot analysis, when we pooled the data, we rejected the hypothesis that the coefficients of $D_{i,nBM}$ and $Q_i$ are the same across the positive and negative revisions in misalignment estimates. These results are available from the authors.

It was noted that non-participation of the 1993 survey or poor data quality could impact the ability of using national data to infer and project the 2005 PPP data. Thus, the revision attributed to the latest 2005 ICP survey is expected to be large for $D_{i,nBM}$ =1 or $Q_i$ =1. For the *PWT* 6.3 and *WDI* 2007 datasets, different indexing methods are used to construct PPP-based real exchange rates from the same 1993 ICP survey. Thus, the implication of non-participation and data quality for the PWT-WDI differential is, a priori, not clear.

The results of estimating (4a) and (4b) are reported in, respectively, Panels A and B of Table 3. The two measurement-related variables are individually and jointly significant in the positive WDI revision regression. They both obtained positive coefficient estimates and jointly explain 38.4% of the revision variability. The positive $D_{i,nBM}$ effect accords with the decomposition results described in the previous subsection. Compared with benchmark countries, countries that did not participate in the 1993 ICP survey experienced larger revisions in their misalignment estimates. Similarly, countries with poor data quality also tend to have their degrees of undervaluation revised more substantially than those with better data quality. Apparently, the data derived directly from the latest 2005 ICP survey tend to reduce the estimated level of undervaluation experienced by these non-benchmark countries.

For positive PWT-WDI differentials, the effect of the non-benchmark dummy variable is positive but insignificant. The insignificance could be attributed to the fact that both datasets are based on the same 1993 ICP survey. The data quality effect is, however, significantly positive albeit its explanatory power is lower than for the case of WDI revisions. The result suggests that the different procedures used by WDI and PWT to estimate the non-survey data are affected differently by data quality. Specifically, compared with the WDI data, the PWT data tend to assign a smaller estimated degree of undervaluation.

The two measurement-related variables offer a relatively weak explanatory power for negative revisions in misalignment estimates. In Panel B of Table 3, the non-benchmark dummy variable is not significant. The data quality dummy variable, on the other hand, has a significant negative effect on revisions in misalignment estimates. That is, among the countries with negative misalignment revisions, those with low data quality tend to experience greater degrees of revision than those with better quality data. The adjusted R-squared estimates are smaller than the corresponding ones in Panel A.

The coefficient estimates of the benchmark and data quality dummy variables have similar signs in the WDI revision and PWT-WDI regressions. Nevertheless, as indicated by adjusted R-squared estimates, these dummy variables are better in explaining the WDI revisions than the PWT-WDI differentials. The improved data collection procedure implemented by the 2005 ICP survey is likely to be the main driver of the difference in misalignment estimates obtained from the different versions of PPP-based data.

## 3.3 Regression Analysis II: Economic Factors

The effects of economic factors on misalignment estimate revisions are examined using the regressions

$$\Delta \hat{u}^{+}_{i,v2,v1} = \alpha_0 + \beta_1 IY_i + \beta_2 AG_i + \beta_3 OG_i + \beta_4 AI_i + \varepsilon_i \,, \quad (5a)$$

and

$$\Delta \hat{u}^{-}_{i,v2,v1} = \alpha_0 + \beta_1 IY_i + \beta_2 AG_i + \beta_3 OG_i + \beta_4 AI_i + \varepsilon_i \,. \quad (5b)$$

The economic factors included in the regression analysis are a) $IY_i$, the initial output level given by the 1993 real *per capita* GDP, b) $AG_i$, the average growth rate given by the average annual real *per capita* GDP growth rate between 1993 and 2005, c) $OG_i$, the average growth in openness, given by the average annual growth rate of degree of openness and the openness measured by the ratio of the sum of exports and imports to GDP, and d) $AI_i$, the average inflation rate given by the average annual inflation rate between 1993 and 2005.

The choice of the two output variables is motivated by the Penn effect specification, which implies a positive empirical relationship between real exchange rate and income level. When growth is accompanied with a shift of consumption towards nontradables (Bergstrand, 1991; Bergin, Glick and Taylor, 2006), this can affect the PPP-based real exchange rate via the direct income channel and the change in consumption composition channel. The usual national price index may capture the general price pattern but not the shift in consumption composition. If it is the case, the WDI 2007 dataset that uses the usual national price information to derive its post-1993 data may understate the 2005 PPP-based real exchange rates of fast growing countries and, hence, tend to overstate their degrees of undervaluation.

Under the convergence hypothesis, a country with a lower level of initial output tends to experience a higher rate of growth. The migration from low to high income is likely to be accompanied by a large shift in consumption composition. Thus, we anticipate that the initial level of output and average growth rate have, respectively, a negative and a positive impact on the WDI revision between the 2008 and 2007 datasets.

Trade openness is perceived to be another factor that affects a country's price level. Kravis and Lipsey (1987), for instance, notes that trade openness would move a country's price level towards the world price level by promoting the convergence of prices of tradables. It could have a positive effect on prices for low income countries and a negative effect for high income countries. The inclusion of trade openness in Penn effect type regressions is reported in, for example, Broda (2006) and Aizenman (2008). In the current exercise, we perceive that the change in the degree of trade openness could have either a positive or negative misalignment estimate revision effect.

The inflation variable is included to capture the inflation effect on using national data to construct PPP-based data beyond the ICP survey year. With benign and moderate inflation, the changes in individual prices are relatively small. These small changes and the price stickiness inertia could prevent individual prices from adjusting freely and reflecting the appropriate relative prices. The situation is quite different under a high inflation environment. With large price variations, individual prices are prone to adjust, in terms of both absolute and relative levels, which are key factors in measuring the PPP-based price level. Compared with a low inflation country, the PPP-based price derived from the national price data of a high inflation country is expected to be better and closer to the one obtained from the 2005 ICP survey. Thus, a country with a high inflation rate is likely to experience a small price revision and, hence, a small revision in its misalignment estimates.

The main difference between the PWT and WDI 2005 data is the way national price levels are constructed from the 1993 ICP survey and updated from subsequent national accounting information. How do the four economic factors mentioned above interact with these statistical procedures? What are the implications for misalignment estimates? We do not anticipate the presence of a systematic interaction pattern or implication for misalignment estimates. Indeed, the difference between results from WDI revision and PWT-WDI differential data indicates the relevance of these factors in interpreting alternative misalignment estimates.

The results of estimating (5a) and (5b) are presented in Table 4. Among the four economic factors, only the initial output level displays a significant effect on positive WDI revisions (Panel A). It has a negative coefficient estimate; that is, a lower initial output level implies a larger reduction in the undervaluation estimate. The finding is in line with the view that the commonly used price indexes could underestimate the PPP-based real exchange rates of countries with low initial output levels. Thus, the PPPs from the 2005 ICP survey for these countries tend to be higher than those estimated from national data and correspond to lower degrees of undervaluation.

Similar to WDI revisions, positive PWT-WDI differentials are negatively affected by initial output levels. The average economic growth variable is negatively significant by itself but insignificant in the presence of other economic factors. Compared with WDI revisions, the initial output level provides a notably lower level of explanatory power for PWT-WDI differentials.

The results in Panel B show that the negative WDI revisions and PWT-WDI differentials are affected by some of these economic factors, though the explanatory power as measured by the adjusted R-squared estimate is limited. The initial output has a positive effect, in contrast to the negative effect reported in Panel A. For countries with a negative change in misalignment estimates, a low level of initial output implies that the estimated level of undervaluation from the WDI 2007 dataset is likely to be smaller than the corresponding ones from the WDI 2008 and PWT 6.3 datasets.

Taking the results in both Panel A and Panel B into consideration, an alternative interpretation is that, compared with high income countries, for countries with low initial output levels in the WDI 2008 and PWT 6.3 dataset their misalignment estimates are further away from the corresponding ones derived from the WDI 2007 dataset. That is, a low initial output is associated with a large data revision.

The average growth rate effect in Panel B is positive, though it attains only modest statistical significance in some cases. The positive effect is in line with the view that the usual price index tends to understate the PPP of a high growth country. This result, combined with the mostly negative growth rate effect in Panel A, also indicates a smaller misalignment revision for countries with high growth rates.

The average inflation rate is the other economic variable that displays a significant effect on negative PWT-WDI differentials (Panel B). Its effect is significantly negative by itself and in the presence of the other three factors. That is, for countries with a higher inflation rate, the PWT dataset tends to yield a larger undervaluation estimate than the WDI data.

In sum, there is evidence that the misalignment revision is affected by some of the selected economic factors. These economic factors display different effects for positive and negative changes in misalignment estimates. Their explanatory powers appear to be weaker than the measurement-related variables in Table 3. In Subsection 3.1 and Table 2, it is documented that, in general, changes in measured PPP-based exchange rates, rather than changes in estimated equilibrium rates, have a strong effect on misalignment revisions. The larger role of changes in data on price levels in the decomposition exercise could explain the superior performance of measurement-related variables.

## 3.4 Regression Analysis III: A Combined Model

In the last two subsections, it is shown that revisions in misalignment estimates are affected by measurement-related and economic factors. The observed effects, however, tend to vary across positive and negative revisions. Since each of these two types of factors exhibits some explanatory power, the results in Tables 3 and 4 may suffer from the omission of either the measurement-related or economic factors. For instance, the significance of, say, the measurement-related factors may be spurious and attributable to their association with the underlying economic factors. To examine the possible interaction between these two types of factors and the implication for explaining misalignment estimate revision, we study the combined explanatory power of these two types of factors. To this end, we estimate the regression specifications

$$\Delta\hat{u}^{+}_{i,v2,v1} = \alpha_0 + \alpha_1 D_{i,nBM} + \alpha_2 Q_i + \beta_1 IY_i + \beta_2 AG_i + \beta_3 OG_i + \beta_4 AI_i + \varepsilon_i \,, \qquad (6a)$$

and

$$\Delta\hat{u}^{-}_{i,v2,v1} = \alpha_0 + \alpha_1 D_{i,nBM} + \alpha_2 Q_i + \beta_1 IY_i + \beta_2 AG_i + \beta_3 OG_i + \beta_4 AI_i + \varepsilon_i \,. \qquad (6b)$$

Essentially, (6a) is a combination of (4a) and (5a), and (6b) is a combination of (4b) and (5b). By pooling these two types of factors, we could study the marginal explanatory power of the measurement-related and economic factors.

The results of estimating (6a) and (6b) and their parsimonious specifications are presented in Table 5. The non-benchmark and low data quality dummy variables, $D_{i,nBM}$ and $Q_i$, have significantly positive effects on positive WDI revisions (Panel A). The result reinforces the measurement-related variable effects in Panel A of Table 3. In the presence of $D_{i,nBM}$ and $Q_i$, the initial output variable becomes insignificant, and the average economic growth rate is the only significant economic factor and has a positive effect. The adjusted R-squared estimates are quite large and above the 40% level. They are larger than the corresponding individual adjusted R-squared estimates but less than their sums. In comparing the adjusted R-squared estimates in Tables 3, 4, and 5, it is noted that the marginal explanatory power of economic factors, in the presence of measurement factors, is quite low for the positive WDI revisions.

The evidence indicates that the measurement-related factors and the economic growth rate have some common information about the revision in misalignment estimates.

At the same time, they also have their own unique information about these revision estimates.

In the case of positive PWT-WDI differentials, the initial output factor is the only significant factor and has a negative coefficient estimate. Apparently, the low data quality effect in Table 3 is spurious and becomes insignificant in the presence of economic factors. In passing, we note that dropping the insignificant variables from the reported parsimonious specification could lead to a substantial decrease in its adjusted R-squared estimate. Thus, even though the average openness growth rate and average inflation rate are not statistically significant, their presence in the regression with other factors improve the model's ability to explain revisions in misalignment estimates.

In the last two sub-sections, it is noted that the selected factors explain better the positive changes in misalignment estimates than the negative ones. The same phenomenon is observed in Table 5. The adjusted R-squared estimates for the parsimonious specifications in Panel B are noticeably smaller than those in Panel A. The low data quality variable has a negative effect while the average economic growth rate has a positive impact on WDI revision regression in Panel B. Again, we note that dropping the insignificant variables from the reported parsimonious specification could lead to a substantial decrease in its adjusted R-squared estimate.

Both the initial output level and average economic growth have positive effects on negative PWT-WDI differentials. These negative revisions are, on the other hand, negatively affected by the average inflation rate. While the average growth and inflation effects are in accordance with those we stipulated for WDI revisions, the initial output effect is not. These economic factors explain about 20% of the variability of negative PWT-WDI differentials.

Comparing the results, we observe that WDI revisions are affected by both the measurement-related and economic factors and that PWT-WDI differentials are not influenced by the measurement-related factors in the presence of economic variables. The systematic implications of the measurement factors for assessing the extent of misalignment are beyond the effect of using different statistical procedures in constructing the PPP-based data. The measurement factors are not directly related to any exchange rate model. However, they could affect some characteristics of the raw prices that are used to construct and infer PPP-based data and affect the estimation of exchange rate misalignment. Our results also indicate that these selected factors have different impacts on positive and negative revisions.

Figure 4 displays the actual and model-predicted misalignment estimate revisions for the four BRIC countries. In each chart, actual misalignment revisions are plotted against their predicted values calculated from the respective models with measurement-related factors, with economic factors, and with the combination of these two types of factors.

For the WDI revisions, the Chinese and Indian misalignment estimate revisions are quite well explained by these models (Figure 4.A). The magnitudes of these two misalignment revisions are quite comparable to those predicted by measurement-related factors, economic factors, and their combination.

The predictions of these models, however, do not work very well for Brazil and Russia. Especially for Brazil, the models' predicted values are quite different from the actual misalignment revisions experienced by these two countries.

A comparison of Figures 4.A and 4.B reaffirms the previous observation that these models are better at describing WDI revisions than PWT-WDI differentials. Specifically, in Figure 4.B, the gaps between the predicted values and the actual revision numbers are usually noticeably larger than those in Figure 4.A. These models, in general, are less capable of capturing the BRIC countries' PWT-WDI differentials.

## 3.5 Some Additional Analyses

A few additional analyses were conducted to assess the robustness of the results presented in the previous subsections. While the Penn effect is a well-established empirical relationship, some studies including Kravis and Lipsey (1987) and Cheung, Chinn and Fujii (2007) have noted that advanced and developing economies could exhibit different degrees of real exchange rate and income interaction. If it is the case, then the exchange rate misalignment assessment exercise based on equation (1) could be imprecise. Naturally, it has implications for the observed revision of misalignment estimates. To explore this possibility, we consider the modified Penn effect regression given by

$$r_i = \beta_0 + \gamma_0 D_{i,ADV} + \beta_1 y_i + \gamma_1 D_{i,ADV} y_i + u_i \, , \qquad (7)$$

where $D_{i,ADV}$ assumes the value of one if country $i$ is an advanced economy according to the IMF classification and the value of zero otherwise.[9]

The estimation results of (7) summarized in Table 6 indicate that the advanced economy dummy variable $D_{i,ADV}$ and/or the interaction variable $D_{i,ADV} y_i$ are statistically significant. For all three datasets, the coefficient of $D_{i,ADV}$ is significant; that is, the intercept estimates are different for advanced and developing economies. However, only the WDI 2007 data give a significant interaction variable $D_{i,ADV} y_i$; its positive estimate means the advanced economies exhibit a stronger Penn effect. For each dataset, the extended model (7) yields a higher adjusted R-squared estimate than the corresponding one in Table 1.

The separation of advanced from developing economies has a systematic effect on the four BRIC countries' misalignment estimates (Panel B). In all cases, there is a discernable decrease in the estimated level of undervaluation. The Russian ruble experiences the largest decrease in its undervaluation estimate among the four BRIC currencies in each of the three modified Penn effect regressions.

For the benchmark and non-benchmark countries, the misalignment estimates display a pattern similar to that in Table 1. While the misalignment estimates from (1) and (7) seem to differ, their correlation estimates are high: 0.923 and 0.800 for *WDI*2007 and *WDI*2008, respectively.

When the WDI revision and PWT-WDI differential constructed from misalignment estimates based on the modified Penn effect regressions are used to repeat the analyses reported in subsections 3.1 to 3.4, the results are qualitatively similar to those reported in Tables 2 to 5. These results are provided in Tables A2-A5 of Appendix D for reference. Specifically, the changes in misalignment estimates are dominated by differences in PPP-based real exchange rate data rather than differences in estimated equilibrium rates. The effects of measurement-related and economic factors are also comparable to those presented above.

Besides the three PPP-based datasets discussed in previous subsections, we study the *WDI* 2010 dataset downloaded in March 2010, being the most current data to compare the currency misalignment estimates. It turned out that the results pertaining to the *WDI*

[9] Our sample includes 28 of the 30 advanced countries as labeled by the IMF in its *World Economic Outlook* publication. Cyprus and Taiwan were not included due to data unavailability.

2010 data are quite similar to those of the *WDI* 2008. We also considered the 1993 Penn effect regression; these results are qualitatively similar to those of the 2005 regression results. These results, for brevity, are not reported here but are available from the authors.

# 4 Concluding Remarks

We investigate the implications of using different datasets for evaluating exchange rate misalignment. Specifically, two WDI datasets and one PWT dataset are used to assess the sensitivity of exchange rate misalignment estimates to different vintages of internationally comparable data derived from the ICP surveys. One WDI dataset and the PWT dataset are based on the 1993 ICP survey, but adopt different methods to derive PPP-based data from the survey results. The other WDI dataset is based on the 2005 ICP survey information. We focus on the year 2005 misalignment estimates from Penn effect regressions.

It is known that the 2005 ICP survey has led to some large revisions of the previously estimated data on internationally comparable price indices and real exchange rates. Do the empirical results based on data derived from previous ICP surveys survive these data revisions?

It is found that, compared with revisions based on different indexing and projection methods, the ICP revision has stronger implications for the estimated degree of misalignment. Essentially, the ICP revision could yield a large change in a country's PPP-based real exchange rate and hence in its estimated degree of exchange rate misalignment. Our decomposition exercise documents the substantial effect of revision in PPP-based real exchange rate data on the revision in misalignment estimates.

We investigated the effect of two measurement-related factors; namely a country's participation status in the 1993 ICP survey and its data quality, and four economic factors: initial output level, average growth rate, average openness growth rate, and average inflation growth rate. It is found that revisions related to the ICP survey update are associated with both measurement-related and economic factors. The difference between WDI and PWT misalignment estimates based on the same ICP survey data, on the other hand, is mainly affected by certain economic factors. Further, these factors explain the positive changes better than the negative ones; the adjusted R-squared estimate for the former could be as high as 42%; that of the latter is about 20%.

The drastic changes in data derived from the 2005 ICP survey undoubtedly raise the concern about the relevance and usefulness of exchange rate misalignment estimates. Note that ICP is considered a good and reliable source for internationally comparable price data, which facilitate cross-country comparisons. Our exercise affirms the sensitivity of misalignment estimates to the new (2005) ICP survey results.

Our study sheds light on the sources of changes in exchange rate misalignment estimates across a few data vintages. While we have some qualitative predictions about the implications of the selected variables, we do not have a strong theory to link these factors to misalignment estimates. For instance, the effects of the measurement-related and economic variables could affect a country's PPP-based output and these effects could vary across countries with different economic and structural characteristics. We could not be sure about their exact implications for estimating the Penn effect and hence the degree of currency misalignment. The results pertaining to, say, the four BRIC countries illustrate that misalignment revision could vary greatly across individual countries. In view of this, we should avoid over-interpreting these results even though the explanatory power of the selected factors is quite good. Further analyses of the underlying causes of changes in misalignment estimates are warranted.

What does our exercise contribute to the recent debate on currency misalignment? One obvious implication is the difficulty of estimating the equilibrium exchange rate and hence of assessing the extent of misalignment. Our results show that the magnitude of an exchange rate misalignment estimate depends on the way the PPP-based data are constructed. The drastic changes in misalignment estimates across different ICP vintage data illustrate an uncertainty of estimating the equilibrium exchange rate that is not commonly discussed in studies on currency misalignment.

Perhaps, it is the factors that affect the revision in misalignment estimates, and not the revision itself, that are surprising. While the dependency result is not unexpected, it is not desirable because the estimated level of misalignment may not be related to the underlying theoretical equilibrium value. How much weight should one assign to a misalignment estimate in considering the state of the economic and policy matters? If the estimate itself is heavily influenced by measurement-related factors unrelated to the economic determinants of an equilibrium exchange rate, then how well advised is to use the estimate to assess the actual level of misalignment and its implications for, say, global imbalances?

It is anticipated that our exercise would not prevent policymakers and commentators from making assertions about a country's extent of misalignment. The current debate on, for example, the Chinese RMB's valuation is a typical and topical example. Nevertheless, we should be aware of the fragility of the exchange rate misalignment assessment exercise. At the same time, it will be of interest to discover the implications for the misalignment assessment exercise of the planned 2011 ICP survey (http://siteresources.worldbank.org/ICPEXT/Resources/ICP_2011.html), which promises innovations and improvements in methodologies and wide country coverage.

# Appendix

# A: Country Sample*

Albania [b, c] , Algeria, Angola [b], Argentina, Armenia [c], Australia [a], Austria [a], Azerbaijan [c], Bahrain, Bangladesh, Belarus [c], Belgium [a], Belize [c], Benin, Bolivia, Botswana, Brazil, Bulgaria [c], Burkina Faso [b], Burundi [b] , Cambodia [b, c], Cameroon, Canada [a], Cape Verde [b] , Central African Republic [b] , Chad [b] , Chile, China [b] , Colombia [b] , Comoros [b] , Democratic Republic of Congo [b, c], Republic of Congo, Costa Rica, Cote d'Ivoire [b] , Croatia [c], Czech Republic [c], Denmark [a], Djibouti [b, c] , Dominica, Dominican Republic, Ecuador, Arab Republic of Egypt, El Salvador, Eritrea [c], Estonia [c], Ethiopia [b] , Fiji, Finland [a], France [a], Gabon, Gambia [b] , Georgia [c] , Germany [a], Ghana [b] , Greece [a], Guinea, Guinea-Bissau [b] , Guyana, Haiti, Honduras, Hong Kong SAR of China [a], Hungary, Iceland [a], India [b] , Indonesia, Islamic Republic of Iran, Ireland [a], Israel [a, b] , Italy [a], Jamaica, Japan [a], Jordan, Kazakhstan [c], Kenya, Kiribati [c] , Republic of Korea [a], Kuwait, Kyrgyz Republic [c], Lao PDR [c], Latvia [c], Lebanon [c], Lesotho [b] , Lithuania [c], Luxembourg [a], Macedonia [b, c] , Madagascar, Malawi, Malaysia, Mali, Malta [b] , Mauritania [b] , Mauritius, Mexico, Federate States of Micronesia [c], Moldova [c], Mongolia [c], Morocco, Mozambique [b], Namibia [c], Nepal, Netherlands [a], New Zealand [a], Nicaragua, Niger [b] , Nigeria, Norway [a], Pakistan, Panama, Papua New Guinea, Paraguay [b], Peru, Philippines, Poland, Portugal [a], Romania, Russian Federation [c], Rwanda [b] , Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore [a], Slovak Republic [c], Slovenia [a,c], Solomon Islands, South Africa [b] , Spain [a], Sri Lanka, St. Vincent and the Grenadines, Sudan [b] , Swaziland, Sweden [a], Switzerland [a], Syrian Arab Republic, Tajikistan [c], Tanzania, Thailand, Togo [b] , Tonga, Trinidad and Tobago, Tunisia, Turkey, Uganda [b] , Ukraine [c], United Arab Emirates, United Kingdom [a], United States [a], Uruguay, Uzbekistan [c], Vanuatu, Venezuela, Vietnam [c], Republic of Yemen, Zambia.

*Superscripts “a”, “b”, and “c” respectively indicate the advanced economies by the IMF definition, the non-benchmark countries of the 1993 ICP program, and the countries whose data quality rating is not available in Summers and Heston (1991).

# B: Data Sources

The data are from the World Bank's World Development Indicator Database and Penn World Table 6.3. The two versions of the WDI data were downloaded in July 2007 and April 2008. The July 2007 vintage (*WDI 2007*) data do not reflect revisions based on the 2005 International Comparison Program, while the April 2008 vintage (*WDI 2008*) data do. The *PWT 6.3* data were downloaded in December 2010. We also downloaded the WDI data in December 2010, being the most recent vintage, to check robustness of our findings.

# C: Additional Misalignment Estimates

Table A1 Implied misalignment

| Country | 2007 | 2008 | PWT | Country | 2007 | 2008 | PWT |
|---|---|---|---|---|---|---|---|
| Albania* | 13.05 | -7.51 | 32.66 | Estonia | -3.97 | -9.07 | 5.87 |
| Algeria | -10.74 | -3.36 | 11.30 | Ethiopia* | -49.63 | -13.43 | -43.66 |
| Angola* | 99.19 | 10.88 | 65.66 | Fiji | 13.80 | 54.63 | 24.12 |
| Argentina | -65.16 | -33.78 | -52.86 | Finland | 29.16 | 42.23 | 49.64 |
| Armenia | -27.00 | -22.47 | -77.79 | France | 31.63 | 35.63 | 44.47 |
| Australia | 28.53 | 26.28 | 28.00 | Gabon | 53.98 | -23.78 | 48.25 |
| Austria | 23.69 | 27.94 | 33.41 | Gambia, The* | -65.39 | -26.47 | -23.52 |
| Azerbaijan | -37.14 | -33.61 | -44.37 | Georgia | 12.76 | -13.57 | -84.38 |
| Bahrain | 11.44 | -22.09 | 9.92 | Germany | 32.82 | 32.56 | 40.64 |
| Bangladesh | -41.41 | 4.31 | -55.88 | Ghana* | -53.61 | 15.07 | 15.29 |
| Belarus | -29.24 | -47.78 | -136.17 | Greece | 13.07 | 10.07 | 22.64 |
| Belgium | 25.34 | 32.12 | 37.72 | Guinea | -76.89 | -4.05 | -131.81 |
| Belize | 7.97 | -4.98 | -17.95 | Guinea-Bissau* | 2.70 | 39.29 | 58.14 |
| Benin | 57.21 | 15.29 | 43.21 | Guyana | -58.29 | -32.26 | 37.51 |
| Bolivia | 2.91 | -52.75 | -22.02 | Haiti | 4.18 | 9.67 | 19.53 |
| Botswana | -24.51 | -27.28 | 15.90 | Honduras | -11.53 | -21.28 | 11.80 |
| Brazil | -2.85 | -3.25 | 2.60 | Hong Kong | -18.16 | -13.08 | -21.08 |
| Bulgaria | -34.27 | -46.10 | -16.05 | Hungary | -13.06 | -5.78 | 9.41 |
| Burkina Faso* | 22.56 | 9.15 | 19.47 | Iceland | 48.76 | 62.54 | 54.12 |
| Burundi* | -32.58 | 21.85 | -25.72 | India* | -57.10 | -22.79 | -50.68 |
| Cambodia* | -76.39 | -17.02 | -56.21 | Indonesia | -14.70 | -10.66 | -45.19 |
| Cameroon | 32.48 | 16.67 | 13.27 | Iran, Islamic Rep. | -38.50 | -68.80 | -49.98 |
| Canada | 17.50 | 19.31 | 22.79 | Ireland | 32.12 | 44.72 | 43.35 |
| Cape Verde* | -31.17 | 60.65 | -27.76 | Israel* | -13.62 | 11.27 | 23.01 |
| Cent. African Rep.* | 7.10 | 48.91 | 57.07 | Italy | 25.26 | 33.08 | 38.28 |
| Chad* | 36.48 | 9.66 | -21.36 | Jamaica | 72.11 | -7.60 | -10.70 |
| Chile | -1.42 | -4.53 | -36.80 | Japan | 29.28 | 37.90 | 44.85 |
| China* | -64.43 | -14.39 | -50.57 | Jordan | -6.58 | 7.81 | 12.67 |
| Colombia* | -30.21 | -3.65 | -15.20 | Kazakhstan | -6.10 | -27.64 | -65.19 |
| Comoros* | 4.72 | 48.74 | 6.35 | Kenya | 53.14 | 5.47 | -11.69 |
| Congo, Dem. Rep.* | -20.30 | 62.70 | 65.72 | Kiribati | -91.45 | -99.55 | 2.45 |
| Congo, Rep. | 135.21 | 17.99 | 19.43 | Korea, Rep. | -0.59 | 5.10 | 7.33 |
| Costa Rica | -21.07 | -9.09 | -14.34 | Kuwait | 42.05 | -20.58 | -2.25 |
| Cote d'Ivoire* | 64.16 | 36.00 | 16.83 | Kyrgyz Republic | -21.29 | -33.77 | -103.59 |
| Croatia | 7.83 | 2.49 | 19.40 | Lao PDR | -26.77 | -31.83 | -28.28 |
| Czech Republic | -20.44 | -17.34 | -5.10 | Latvia | -21.45 | -20.41 | 3.13 |
| Denmark | 47.66 | 54.58 | 63.35 | Lebanon | 89.22 | -5.49 | 40.93 |
| Djibouti* | 25.30 | 15.79 | -25.97 | Lesotho* | -43.04 | 35.90 | 6.91 |
| Dominican Rep. | -25.08 | 16.41 | -7.65 | Lithuania | -20.99 | -19.41 | 1.32 |
| Ecuador | 43.72 | -24.95 | 8.90 | Luxembourg | 20.78 | 20.28 | 7.75 |
| Egypt, Arab Rep. | -38.81 | -61.65 | -54.61 | Macedonia, FYR* | -22.72 | -37.23 | -2.86 |
| El Salvador | 6.43 | -9.32 | 13.54 | Madagascar | 23.20 | -0.18 | 35.38 |
| Eritrea | -22.43 | -0.50 | 47.18 | Malawi | 15.50 | 8.73 | -27.95 |

Table A1 continued

| Country | 2007 | 2008 | PWT | Country | 2007 | 2008 | PWT |
|---|---|---|---|---|---|---|---|
| Malaysia | -19.63 | -31.16 | -57.92 | Sierra Leone | 19.07 | 22.54 | -63.67 |
| Mali | 44.92 | 29.79 | 41.09 | Singapore | 8.76 | -27.91 | -16.71 |
| Malta* | 1.59 | -0.31 | 13.74 | Slovak Republic | -19.60 | -19.49 | -1.15 |
| Mauritania* | -17.58 | -6.33 | 5.55 | Slovenia | 3.06 | 2.98 | 9.02 |
| Mauritius | -42.53 | -17.82 | -85.30 | Solomon Islands | -1.11 | -5.75 | 78.41 |
| Mexico | 19.17 | 4.72 | 24.94 | South Africa* | -23.11 | 5.04 | 2.09 |
| Micronesia, Fed. | -53.65 | -32.05 | 64.26 | Spain | 17.05 | 20.73 | 23.47 |
| Moldova | 4.92 | -19.34 | -55.48 | Sri Lanka | -47.59 | -28.07 | -64.63 |
| Mongolia | 10.40 | -21.98 | 3.77 | St. Vincent & the Gre. | 14.05 | -12.20 | 63.06 |
| Morocco | -10.62 | 16.33 | -16.18 | Sudan* | 15.20 | 14.26 | 40.88 |
| Mozambique* | 3.98 | 44.16 | -59.97 | Suriname | -27.07 | -3.16 | -33.43 |
| Namibia | -23.66 | 29.87 | 17.64 | Swaziland | 15.95 | 4.18 | -38.46 |
| Nepal | -47.09 | -7.23 | -50.47 | Sweden | 34.95 | 42.27 | 53.97 |
| Netherlands | 30.72 | 29.94 | 40.27 | Switzerland | 44.40 | 49.76 | 54.54 |
| New Zealand | 31.29 | 37.19 | 44.01 | Syrian Arab Rep. | -7.49 | -24.99 | 58.12 |
| Nicaragua | -46.04 | -24.94 | 31.89 | Tajikistan | -2.19 | -44.67 | -105.48 |
| Niger* | 35.64 | 35.76 | 28.48 | Tanzania | 68.05 | 4.70 | 60.06 |
| Nigeria | 98.04 | 23.40 | 37.46 | Thailand | -51.27 | -33.31 | -46.15 |
| Norway | 49.70 | 42.71 | 48.27 | Togo* | -15.63 | 36.40 | 69.60 |
| Pakistan | -9.18 | -25.92 | -39.21 | Tonga | -70.58 | -21.43 | -29.51 |
| Panama | 22.18 | -0.51 | 24.31 | Trinidad and Tobago | 16.23 | 10.54 | -17.99 |
| Papua New Guinea | -3.17 | 18.77 | 23.81 | Tunisia | -42.43 | -17.72 | -49.91 |
| Paraguay* | -49.53 | -38.49 | -44.50 | Turkey | 13.44 | 12.85 | 39.31 |
| Peru | 1.42 | -17.05 | 13.41 | Uganda* | -27.69 | 9.03 | 10.21 |
| Philippines | -63.19 | -14.47 | -46.74 | Ukraine | -63.51 | -46.79 | -84.07 |
| Poland | -9.05 | -9.91 | 8.98 | United Kingdom | 23.77 | 37.58 | 46.45 |
| Portugal | 16.18 | 20.62 | 30.40 | United States | 5.90 | 14.36 | 14.91 |
| Romania | -6.68 | -19.37 | 9.73 | Uruguay | -13.43 | -8.43 | -22.47 |
| Russian Federation | -15.44 | -33.39 | -17.73 | Uzbekistan | -18.96 | -37.84 | -3.92 |
| Rwanda* | -26.15 | 7.00 | -7.04 | Vanuatu | 30.54 | 6.56 | -21.21 |
| Samoa | -27.72 | -11.41 | -15.44 | Venezuela, RB | 50.61 | -8.77 | -3.08 |
| Saudi Arabia | 19.85 | -12.93 | -15.77 | Vietnam | -56.58 | -32.05 | -59.66 |
| Senegal | 28.46 | 23.19 | 25.68 | Yemen, Rep. | 119.70 | -11.08 | 106.88 |
| Seychelles | -26.43 | -6.89 | -14.22 | Zambia | 92.52 | 44.35 | 23.54 |

Notes: The misalignment estimates in percentages derived from the Penn effect regression (1) are presented. The entries under the column headings "2007","2008" and "PWT" are the estimates based on *WDI* 2007, *WDI* 2008 and *PWT*6.3, respectively. Positive (negative) misalignment estimates indicate overvaluation (undervaluation). * indicates that the corresponding country did not participate in the 1993 ICP survey (non-benchmark country).

# D: Results Based on Modified Penn Effect Regression

The results of analyzing misalignment revisions that are derived from *the modified Penn effect regressions* are presented in the table layout similar to the one used in the main text.

Table A2 Decomposition of Differences in the 2005 Misalignment Estimates for the Modified Penn Effect Regression Model

| | $n$ | $\Delta\hat{u}_{i,v2,v1}$ | $\Delta r_{i,v2,v1}$ | $-\Delta\hat{r}_{i,v2,v1}$ | $-\Delta income$ | $-\Delta Penn$ |
|---|---|---|---|---|---|---|
| *A. WDI revision* | | | | | | |
| Total | 154 | 0 | .116 | -.116 | .028 | -.145 |
| Benchmark | 122 | -.063 | .046 | -.104 | .009 | -.113 |
| Non-benchmark | 32 | .243 | .386 | -.163 | .100 | -.264 |
| $\Delta\hat{u}^{+}_{i,v2,v1}$ | 79 | .224 | .302 | -.077 | .076 | -.154 |
| $\Delta\hat{u}^{-}_{i,v2,v1}$ | 75 | -.236 | -.078 | -.157 | -.022 | -.135 |
| *B. PWT-WDI differential* | | | | | | |
| Total | 154 | 0 | -.031 | .031 | -.014 | .046 |
| Benchmark | 122 | -.034 | -.064 | .030 | -.022 | .052 |
| Non-benchmark | 32 | .129 | .093 | .036 | .015 | .021 |
| $\Delta\hat{u}^{+}_{i,v2,v1}$ | 83 | .237 | .152 | .085 | .036 | .048 |
| $\Delta\hat{u}^{-}_{i,v2,v1}$ | 71 | -.277 | -.245 | -.031 | -.074 | .042 |
| *C. BRIC Countries* | | | | | | |
| *i. WDI revision* | | | | | | |
| China | | .465 | .506 | -.040 | .119 | -.160 |
| India | | .318 | .440 | -.122 | .107 | -.229 |
| Brazil | | .014 | .092 | -.077 | .007 | -.084 |
| Russia | | -.150 | -.088 | -.061 | -.016 | -.045 |
| *ii. PWT-WDI differential* | | | | | | |
| China | | .156 | .070 | .086 | .009 | .076 |
| India | | .066 | .014 | .051 | .006 | .045 |
| Brazil | | .094 | .020 | .074 | -.016 | .091 |
| Russia | | .023 | -.062 | .086 | -.016 | .103 |

Notes: The table entries summarize the decomposition of the changes in misalignment estimates when allowing for different Penn coefficients between advanced and other economies by (7) in the text. The "*n*" column gives the number of countries. The $\Delta\hat{u}_{i,v2,v1}$ column gives changes in misalignment estimates, which have two components: change in PPP-based real exchange rate and change in estimated equilibrium rate that are given in the $\Delta r_{i,v2,v1}$ and $-\Delta\hat{r}_{i,v2,v1}$ columns. The two components of the change in estimated equilibrium rates are in the columns

$\_\Delta income = \_ [(\hat{\beta}_{1,v1} y_{i,v2} + \hat{\gamma}_{1,v1} D_{i,ADV} y_{i,v2}) - (\hat{\beta}_{1,v1} y_{i,v1} + \hat{\gamma}_{1,v1} D_{i,ADV} y_{i,v1})]$,

and

$\_\Delta Penn =$

$-[(\hat{\beta}_{0,v2} + \hat{\gamma}_{0,v2} D_{i,ADV} + \hat{\beta}_{1,v2} y_{i,v2} + \hat{\gamma}_{1,v2} D_{i,ADV} y_{i,v2}) - (\hat{\beta}_{0,v1} + \hat{\gamma}_{0,v1} D_{i,ADV} + \hat{\beta}_{1,v1} y_{i,v2} + \hat{\gamma}_{1,v1} D_{i,ADV} y_{i,v2})]$.

See the text for additional information. In panels A and B, the rows Total, Benchmark, Non-benchmark, $\Delta \hat{u}^{+}_{i,v2,v1}$, and $\Delta \hat{u}^{-}_{i,v2,v1}$, give average values for all countries in the sample, the 1993 survey benchmark countries, the non-benchmark countries, countries with positive misalignment revisions, and countries with negative misalignment revisions. Panel C gives the individual results for BRIC countries.

Table A3 Revision in Misalignment Estimates - the Role of Measurement-related Factors for the Modified Penn Effect Regression Model

| | WDI revision | | | PWT-WDI differential | | |
|---|---|---|---|---|---|---|
| *Panel A.* $\Delta\hat{u}^{+}_{i,v2,v1}$ | | | | | | |
| Non-benchmark | .212**<br>(.048) | | .130*<br>(.050) | .047<br>(.051) | | .018<br>(.057) |
| Low data quality | - | .212**<br>(.030) | .164**<br>(.029) | - | .168**<br>(.035) | .162**<br>(.041) |
| Constant | .159**<br>(.020) | .068**<br>(.012) | .060**<br>(.010) | .223**<br>(.030) | .088**<br>(.017) | .087**<br>(.017) |
| Adjusted $R^2$ | .236 | .226 | .308 | -.003 | .131 | .119 |
| *n* | 79 | 66 | 66 | 83 | 66 | 66 |
| *Panel B.* $\Delta\hat{u}^{-}_{i,v2,v1}$ | | | | | | |
| Non-benchmark | .009<br>(.094) | - | .022<br>(.146) | -.019<br>(.086) | - | .003<br>(.098) |
| Low data quality | - | -.261**<br>(.044) | -.264**<br>(.046) | - | -.219**<br>(.037) | -.219**<br>(.041) |
| Constant | -.237**<br>(.031) | -.049**<br>(.011) | .-049**<br>(.011) | -.275**<br>(.033) | -.063**<br>(.012) | -.063**<br>(.012) |
| Adjusted $R^2$ | -.013 | .131 | .115 | -.013 | .119 | .102 |
| *n* | 75 | 55 | 55 | 71 | 55 | 55 |

Notes: The entries summarize the results of estimating the equations (4a) and (4b) with $\Delta\hat{u}_{i,v2,v1}$'s derived from the modified Penn effect regression (7). Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors of (4a), with positive changes $\Delta\hat{u}^{+}_{i,v2,v1}$ as regressand. Panel B gives coefficient estimates and their heteroskedastic-consistent standard errors of (4b), with negative changes $\Delta\hat{u}^{-}_{i,v2,v1}$ as regressand. ** and * indicate statistical significance at the one and five percent levels, respectively. Entries in the *n* row are numbers of observations. Due to data constraints, the numbers of observations vary across specifications.

Table A4 Revision in Misalignment Estimates - the Role of Economic Factors for the Modified Penn Effect Regression Model

| | WDI revision | | | | | PWT-WDI differential | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Panel A.* $\Delta\hat{u}^{+}_{i,v2,v1}$ | | | | | | | | | | |
| Initial output level | -.084** | - | - | - | -.087** | -.083** | - | - | | -.072** |
| | (.015) | | | | (.016) | (.020) | | | | (.019) |
| Average growth rate | - | -.081 | - | - | .076 | - | -.213* | - | | .051 |
| | | (.096) | | | (.093) | | (.099) | | | (.079) |
| Average openness growth rate | | | -.003 | - | .043 | - | | -.144 | | -.144$^{\dagger}$ |
| | | | (.072) | | (.056) | | | (.094) | | (.080) |
| Average inflation rate | - | - | - | .017 | .010 | - | - | - | .018 | .015 |
| | | | | (.017) | (.017) | | | | (.012) | (.014) |
| Constant | .064* | .245** | .224** | .214** | .029 | .091** | .289** | .232** | .228** | .088* |
| | (.024) | (.033) | (.024) | (.022) | (.037) | (.027) | (.042) | (.025) | (.024) | (.037) |
| Adjusted $R^2$ | .246 | -.001 | -.013 | .044 | .244 | .165 | .044 | .032 | .035 | .246 |
| *n* | 79 | 79 | 76 | 79 | 76 | 83 | 83 | 79 | 83 | 79 |
| *Panel B.* $\Delta\hat{u}^{-}_{i,v2,v1}$ | | | | | | | | | | |
| Initial output level | .081** | - | - | - | .065** | .075** | - | - | - | .070** |
| | (.026) | | | | (.020) | (.023) | | | | (.024) |
| Average growth rate | - | .243$^{\dagger}$ | - | - | .164 | - | .192 | - | - | .258$^{\dagger}$ |
| | | (.137) | | | (.125) | | (.170) | | | (.146) |
| Average openness growth rate | | | .119 | - | .098 | - | | .084 | - | -.021 |
| | | | (.121) | | (.125) | | | (.134) | | (.109) |
| Average inflation rate | - | - | - | -.012 | -.014 | - | - | - | -.035** | -.044** |
| | | | | (.020) | (.022) | | | | (.009) | (.011) |
| Constant | -.068 | -.291** | -.222** | -.228** | -.110$^{\dagger}$ | -.110* | -.325** | -.279** | -.251** | -.143* |
| | (.046) | (.049) | (.027) | (.030) | (.061) | (.043) | (.053) | (.034) | (.029) | (.068) |
| Adjusted $R^2$ | .120 | .030 | .000 | -.001 | .152 | .097 | .014 | -.007 | .090 | .241 |
| *n* | 75 | 74 | 71 | 75 | 70 | 71 | 70 | 68 | 71 | 67 |

Notes: The entries summarize the results of estimating the equations (5a) and (5b) with $\Delta\hat{u}_{i,v2,v1}$'s derived from the modified Penn effect regression (7). Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors of (5a), with positive changes $\Delta\hat{u}^{+}_{i,v2,v1}$ as the regressand. Panel B gives coefficient estimates and their heteroskedastic-consistent standard errors of (5b), with negative changes $\Delta\hat{u}^{-}_{i,v2,v1}$ as regressand. **, * and † indicate statistical significance at the 1%, 5% and 10% levels, respectively. Entries in *n* row indicate the n row indicate numbers of observations. Due to data constraints, the numbers of observations vary across specifications.

Table A5 Revision in Misalignment Estimates – A Combined and Modified Penn Effect Regression Model

| | WDI revision | | PWT-WDI differential | |
|---|---|---|---|---|
| *Panel A*: $\Delta\hat{u}^{+}_{i,v2,v1}$ | | | | |
| Non-benchmark | .104 | .129* | -.064 | - |
| | (.063) | (.050) | (.068) | |
| Low data quality | .149* | .195** | .025 | - |
| | (.069) | (.029) | (.058) | |
| Initial output level | -.027 | - | -.082* | -.068** |
| | (.037) | | (.039) | (.020) |
| Average growth rate | .222** | .179* | .125 | - |
| | (.076) | (.074) | (.109) | |
| Average openness | -.010 | - | -.168 | -.144 |
| Growth rate | (.061) | | (.123) | (.080) |
| Average inflation rate | -.069$^{\dagger}$ | -.071* | -.037 | .014 |
| | (.037) | (.032) | (.027) | (.013) |
| Constant | -.009 | .006 | .069* | .108** |
| | (.033) | (.025) | (.045) | (.029) |
| Adjusted $R^2$ | .346 | .356 | .171 | .252 |
| *n* | 64 | 66 | 64 | 79 |
| *Panel B*: $\Delta\hat{u}^{-}_{i,v2,v1}$ | | | | |
| Non-benchmark | .114 | - | .099 | - |
| | (.115) | | (.130) | |
| Low data quality | -.074 | -.158** | -.018 | - |
| | (.074) | (.033) | (.089) | |
| Initial output level | .049 | - | .093* | .058* |
| | (.045) | | (.045) | (.023) |
| Average growth rate | .296 | .392$^{\dagger}$ | .191 | .282$^{\dagger}$ |
| | (.210) | (.218) | (.232) | (.147) |
| Average openness | .047 | .02 | -.270 | - |
| growth rate | (.210) | (.192) | (.196) | |
| Average inflation rate | -.083** | -.079** | -.014 | -.044** |
| | (.012) | (.007) | (.020) | (.011) |
| Constant | -.116 | -.168** | -.036 | -.184** |
| | (.069) | (.060) | (.077) | (.065) |
| Adjusted $R^2$ | .296 | .295 | .202 | .223 |
| *n* | 51 | 51 | 51 | 70 |

Notes: The entries summarize the results of estimating the equations (6a) and (6b) with $\Delta\hat{u}_{i,v2,v1}$'s derived from the modified Penn effect regression (7). Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors of (6a), with positive changes $\Delta\hat{u}^{+}_{i,v2,v1}$ as regressand. Panel B gives coefficient estimates and their heteroskedastic-consistent standard errors of (6b), with negative changes $\Delta\hat{u}^{-}_{i,v2,v1}$ as regressand. **, * and $^{\dagger}$ indicate statistical significance at 1%, 5% and 10% levels, respectively. Entries in *n* row indicate numbers of observations. Due to data constraints, the numbers of observations vary by specification.

# References

Aizenman, Joshua. 2008. Relative Price Levels and Current Accounts: An Exploration. *Department of Economics Working Paper* No. 643, University of California, Santa Cruz.

Balassa, Bela. 1964. The Purchasing Power Doctrine: A Reappraisal. *Journal of Political Economy* 72: 584-596.

Bergin, Paul R., Reuven Glick and Alan M. Taylor. 2006. Productivity, Tradability, and the Long-run Price Puzzle. *Journal of Monetary Economics* 53: 2041-2066.

Bergstrand, Jeffrey. 1991. Structural Determinants of Real Exchange Rates and National Price Levels: Some Empirical Evidence. *American Economic Review* 81 (1): 325–334.

Bhagwati, Jagdish. 1984. Why Are Services Cheaper in the Poor Countries? *Economic Journal* 94 (374): 279-286.

Broda, Christian. 2006. Exchange Rate Regimes and National Price Levels. *Journal of International Economics* 70(1): 52-81.

Chen, Shaohua and Martin Ravallion. 2010a. China Is Poorer than We Thought, but No Less Successful in the Fight against Poverty. In *Debates on the Measurement of Global Poverty*, edited by Sudhir Anand, Paul Segal, and Joseph E. Stiglitz, 327–40. New York: Oxford University Press.

Chen, Shaohua and Martin Ravallion. 2010b. The Developing World is Poorer than We Thought, but No Less Successful in the Fight against Poverty. *Quarterly Journal of Economics* 125: 1577-1625.

Cheung, Yin-Wong and Menzie D. Chinn. 1996. Deterministic, Stochastic, and Segmented Trends in Aggregate Output: A Cross-Country Analysis. *Oxford Economic Papers* 48: 134-162.

Cheung, Yin-Wong, Menzie D. Chinn and Eiji Fujii. 2007. The Overvaluation of Renminbi Undervaluation. *Journal of International Money and Finance* 26(5) (September): 762-785.

Cheung, Yin-Wong, Menzie D. Chinn and Eiji Fujii. 2009. Pitfalls in Measuring Exchange Rate Misalignment: The Yuan and Other Currencies. *Open Economies Review* 20: 183–206.

Cheung, Yin-Wong, Menzie D. Chinn and Eiji Fujii, 2010a. Measuring Misalignment: Latest Estimates for the Chinese Renminbi, Chapter 10, 79-90, in Simon Evenett (Editor), The US-Sino Currency Dispute: New Insights from Economics, Politics and Law, A VoxEU.org Publication.

Cheung, Yin-Wong, Menzie D. Chinn and Eiji Fujii, 2010b. Measuring Renminbi Misalignment: Where Do We Stand? *Korea and the World Economy* 11: 263-296.

Ciccone, Antonio, and Marek Jarocinksi. 2010. Determinants of Economic Growth: Will Data Tell? *American Economic Journal: Macroeconomics*, 2(4): 223–47.

Coudert, Virginie and Cecile Couharde. 2007. Real Equilibrium Exchange Rate in China: Is the Renminbi Undervalued? *Journal of Asian Economics* 18 (4): 568–594.

Dawson, John W., Joseph P. DeJuan, John J. Seater, and E. Frank Stephenson. 2001. Economic Information versus Quality Variation in Cross-country Data. *Canadian Journal of Economics* 34(4): 988-1009.

Deaton, Angus and Alan Heston. 2010. Understanding PPPs and PPP-based National Accounts. *American Economic Journal: Macroeconomics* 2: 1–35.

Dunaway, Steven, LAmin Leigh and Xiangming Li. 2009, How Robust are Estimates of Equilibrium Real Exchange Rates: The Case of China, *Pacific Economic Review* 14(3), 361-375.

Eltetö, O. and P. Köves. 1964. “On a Problem of Index Number Computation Relating to International Comparison.” *Statisztikai Szemle*, 42: 507–18.

Frankel, Jeffrey. 2006. On the Yuan: the Choice between Adjustment under a Fixed Exchange Rate and Adjustment under a Flexible Rate. *CESifo Economic Studies* 52 (2): 246-275.

Geary, Roy C. 1958. A Note on the Comparison of Exchange Rates and Purchasing Power between Countries. *Journal of the Royal Statistical Society*, Series A (General), 121(1): 97–99.

Gini, Corrado. 1924. Quelques considerations au sujet de la construction des Nombres Indices des prix et des questions analogues. *Metron*, 4(1): 3–162.

Hu, Chuntian and Zhijun Chen. 2010. Renminbi Already Overappreciated: Evidence from FEERs (1994-2008), *China Economist* 26, 64-78.

IMF, 2011. IMF Quotas, IMF Factsheet, http://www.imf.org/external/np/exr/facts/quotas.htm

Johnson, Simon, Chris Papageorgiou and Arvind Subramanian. 2009. Is Newer Better? The Penn World Table Revisions and the Cross-Country Growth Literature. *NBER Working Paper* 15455.

Khamis, Salem H. 1972. A New System of Index Numbers for National and International Purposes. *Journal of the Royal Statistical Society*, Series A, 135(1): 96–121.

Korhonen, Iikka and Maria Ritola, 2011, “ Renminbi misaligned - Results from meta-regressions,” Chapter 4, Yin-Wong Cheung and Guonan Ma, coedited, *Asia and China in the Global Economy*, World Scientific Publishing Co.

Kravis, Irving B. and Robert E. Lipsey. 1983. *Toward an Explanation of National Price Levels*, Princeton Studies in International Finance No. 52, Princeton, NJ: International Finance Center, Princeton University, 1983.

Kravis, Irving B. and Robert E. Lipsey. 1987. The Assessment of National Price Levels. In *Real Financial Linkages Among Open Economies*, edited by Sven W. Arndt and J. David Richardson. Cambridge, MA: MIT Press, 97-134.

Kravis, Irving B., Alan Heston and Robert Summers. 1978. *International Comparisons of Real Product and Purchasing Power*, Baltimore: The Johns Hopkins University Press.

Milanovic, Branko. 2009. Global Inequality Recalculated: The Effect of New 2005 PPP Estimates on Global Inequality. *World Bank Policy Research Working Paper* 5061.

Ponomareva, Natalia and Hajime Katayama. 2010. Does the Version of the Penn World Tables Matter? An Analysis of the Relationship between Growth and Volatility. *Canadian Journal of Economics* 43: 152-179.

Ravallion, Martin. 2010. Price Levels and Economic Growth: Making Sense of the PPP Changes between ICP Rounds. *The World Bank Policy Research Working Paper* 5229.

Samuelson, Paul A. 1964. Theoretical Notes on Trade Problems. *Review of Economics and Statistics* 46: 145-154.

Samuelson, Paul A. 1994. Facets of Balassa-Samuelson Thirty Years Later. *Review of International Economics* 2: 201-226.

Silver, Mick. 2010. IMF Applications of Purchasing Power Parity Estimates. *IMF Working Paper* WP/08/253.

Summers, Robert and Alan Heston. 1991. The Penn World Table (Mark 5): An Extended Set of International Comparisons, 1950-1988. *Quarterly Journal of Economics* 106: 327-368.

Szulc, B. 1964. "Indices for Multiregional Comparisons." *Przeglad Statystyczny* 3: 239–54.

Wang, Tao and Harrison Hu, 2010, "How Undervalued Is the RMB?" *Asian Economic Perspectives* (13 April 2010), UBS Investment Research.

World Bank. 2008a. *Comparison of New 2005 PPPs with Previous Estimates: Appendix G Revised: Global Purchasing Power Parities and Real Expenditures.* Washington, DC.

World Bank. 2008b. *Global Purchasing Power Parities and Real Expenditures: 2005 International Comparison Program*. International Comparison Program and International Bank for Reconstruction and Development. Washington, DC.

World Bank. 2008c. *ICP 2003-2006 Handbook*, http://go.worldbank.org/MW520NNFK0.

Table 1 The Penn Effect Regression Based on the year 2005 data

| | *WDI* 2007 | *WDI* 2008 | *PWT* 6.3 |
|---|---|---|---|
| *A. Estimation results* | | | |
| GDP per capita | .366** | .249** | .347** |
| | (.028) | (.019) | (.030) |
| Constant | -.058 | -.143** | -.149* |
| | (.052) | (.047) | (.063) |
| Adjusted $R^2$ | .535 | .559 | .468 |
| Number of observations | 154 | 154 | 154 |
| *B. Implied misalignment* (%) | | | |
| China | -64.43 | -14.38 | -50.56 |
| India | -57.09 | -22.78 | -50.67 |
| Brazil | -2.85 | -3.25 | 2.59 |
| Russia | -15.44 | -33.39 | -17.73 |
| *C. By participation status* | | | |
| Benchmark countries | 3.18 [30.35] | -3.19 [22.76] | -.67 [35.38] |
| Non-benchmark countries | -12.13 [32.86] | 12.18 [23.91] | 2.58 [31.02] |

Notes: Results of estimating the Penn effect regression (1) in the text are presented. Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors in parentheses. ** and * indicate statistical significance at 1% and 5% levels, respectively. Panel B gives misalignment estimates of the four BRIC countries in percentages. Positive (negative) misalignment estimates indicate overvaluation (undervaluation). Panel C gives averages (and mean absolute values in brackets) of misalignment estimates of the 1993 benchmark and non-benchmark countries. There are 122 benchmark and 32 non-benchmark countries in the 1993 ICP.

Table 2 Decomposition of Differences in the 2005 Misalignment Estimates

| | $n$ | $\Delta\hat{u}_{i,v2,v1}$ | $\Delta r_{i,v2,v1}$ | $-\Delta\hat{r}_{i,v2,v1}$ | $-\Delta income$ | $-\Delta Penn$ |
|---|---|---|---|---|---|---|
| *A. WDI revision* | | | | | | |
| Total | 154 | 0 | .116 | -.116 | .043 | -.160 |
| Benchmark | 122 | -.063 | .046 | -.109 | .015 | -.125 |
| Non-benchmark | 32 | .243 | .386 | -.143 | .148 | -.291 |
| $\Delta\hat{u}^{+}_{i,v2,v1}$ | 80 | .243 | .298 | -.055 | .110 | -.165 |
| $\Delta\hat{u}^{-}_{i,v2,v1}$ | 74 | -.262 | -.079 | -.183 | -.028 | -.154 |
| *B. PWT-WDI differential* | | | | | | |
| Total | 154 | 0 | -.031 | .031 | -.021 | .052 |
| Benchmark | 122 | -.038 | -.064 | .026 | -.031 | .057 |
| Non-benchmark | 32 | .147 | .093 | .054 | .020 | .033 |
| $\Delta\hat{u}^{+}_{i,v2,v1}$ | 89 | .250 | .145 | .105 | .050 | .054 |
| $\Delta\hat{u}^{-}_{i,v2,v1}$ | 65 | -.342 | -.273 | -0.69 | -.118 | .050 |
| *C. BRIC Countries* | | | | | | |
| *i. WDI revision* | | | | | | |
| China | | .500 | .506 | -.006 | .180 | -.186 |
| India | | .343 | .440 | -.097 | .010 | -.107 |
| Brazil | | -.004 | .092 | -.096 | .161 | -.259 |
| Russia | | -.179 | -.088 | -.091 | -.025 | -.065 |
| *ii. PWT-WDI differential* | | | | | | |
| China | | .138 | .070 | .068 | .015 | .053 |
| India | | .064 | .014 | .050 | -.025 | .059 |
| Brazil | | .054 | .020 | .034 | .009 | .040 |
| Russia | | -.022 | -.062 | 0.40 | -.024 | .064 |

Notes: Decomposition of changes in misalignment estimates. The *n* column gives numbers of countries. The $\Delta\hat{u}_{i,v2,v1}$ column gives changes in misalignment estimates, which have two components: change in PPP-based real exchange rate and change in estimated equilibrium rate given in $\Delta r_{i,v2,v1}$ $-\Delta\hat{r}_{i,v2,v1}$ columns. The two components of the change in estimated equilibrium rates are given in columns $-\Delta income$ and $-\Delta Penn$ where $-\Delta income$ = $-[(\hat{\beta}_{0,v1}+\hat{\beta}_{1,v1}y_{i,v2})-(\hat{\beta}_{0,v1}+\hat{\beta}_{1,v1}y_{i,v1})]$ and $-\Delta Penn$ $=-[(\hat{\beta}_{0,v2}+\hat{\beta}_{1,v2}y_{i,v2})-(\hat{\beta}_{0,v1}+\hat{\beta}_{1,v1}y_{i,v2})]$. See the text for additional information. In panels A and B, rows labeled Total, Benchmark, Non-benchmark, $\Delta\hat{u}^{+}_{i,v2,v1}$, and $\Delta\hat{u}^{-}_{i,v2,v1}$, give average values for all countries in the sample, the 1993 survey benchmark countries, the non-benchmark countries, countries with positive misalignment revisions, and countries with negative misalignment revisions. Panel C gives individual results for BRIC countries.

Table 3 Revision in Misalignment Estimates - the Role of Measurement-Related Factors

| | WDI revision | | | PWT-WDI differential | | |
|---|---|---|---|---|---|---|
| *Panel A.* $\Delta\hat{u}^{+}_{i,v2,v1}$ | | | | | | |
| Non-benchmark | .258** | - | .153** | .061 | - | .030 |
| | (.051) | | (.054) | (.057) | | (.068) |
| Low data quality | - | .239** | .180** | - | .131** | .120* |
| | | (.032) | (.031) | | (.038) | (.047) |
| Constant | .169** | .081* | .074** | .233** | .136** | .135** |
| | (.020) | (.011) | (.008) | (.030) | (.014) | (.013) |
| Adjusted $R^2$ | .291 | .288 | .384 | .001 | .073 | .064 |
| *n* | 80 | 67 | 67 | 89 | 72 | 72 |
| *Panel B.* $\Delta\hat{u}^{-}_{i,v2,v1}$ | | | | | | |
| Non-benchmark | .041 | - | .067 | -.039 | - | -.029 |
| | (.095) | | (.140) | (.100) | | (.113) |
| Low data quality | - | -.304** | -.312** | - | -.284** | -.280** |
| | | (.046) | (.049) | | (.048) | (.051) |
| Constant | -.267** | -.020* | .-020* | -.338** | -.044 | -.044 |
| | (.035) | (.008) | (.008) | (.040) | (.028) | (.028) |
| Adjusted $R^2$ | -.011 | .096 | .083 | -.014 | .069 | .050 |
| *n* | 74 | 54 | 54 | 65 | 49 | 49 |

Notes: The results of estimating the equations (4a) and (4b) are presented. Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors of (4a), with positive changes $\Delta\hat{u}^{+}_{i,v2,v1}$ as regressand. Panel B gives coefficient estimates and their heteroskedastic-consistent standard errors of (4b), with negative changes $\Delta\hat{u}^{-}_{i,v2,v1}$ as regressand. ** and * indicate statistical significance at the 1% and 5% levels, respectively. Entries in *n* row indicate numbers of observations. Due to data constraints, the numbers of observations vary across specifications.

Table 4 Revision in Misalignment Estimates - the Role of Economic Factors

| | WDI revision | | | | | PWT-WDI differential | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Panel A.* $\Delta\hat{u}^{+}_{i,v2,v1}$ | | | | | | | | | | |
| Initial output level | -.098** | - | - | - | -.093** | -.089** | - | - | | -.071** |
| | (.016) | | | | (.017) | (.022) | | | | (.020) |
| Average growth rate | - | -.100 | - | - | -.024 | - | -.287* | - | | -.075 |
| | | (.107) | | | (.104) | | (.108) | | | (.083) |
| Average openness growth rate | | | .009 | - | .039 | - | | -.138 | | -.164 |
| | | | (.086) | | (.070) | | | (.123) | | (.101) |
| Average inflation rate | - | - | - | .021 | .012 | - | - | - | .023† | .019 |
| | | | | (.015) | (.017) | | | | (.013) | (.015) |
| Constant | .063** | .268** | .241** | .232** | .068 | .100** | .320** | .241** | .239** | .136** |
| | (.023) | (.036) | (.026) | (.023) | (.035) | (.029) | (.045) | (.027) | (.025) | (.035) |
| Adjusted $R^2$ | .265 | .002 | -.013 | .060 | .268 | .133 | .071 | .017 | .049 | .239 |
| *n* | 80 | 80 | 77 | 80 | 77 | 89 | 89 | 85 | 89 | 85 |
| *Panel B.* $\Delta\hat{u}^{-}_{i,v2,v1}$ | | | | | | | | | | |
| Initial output level | .104** | - | - | - | .076** | .069* | - | - | - | .066† |
| | (.030) | | | | (.025) | (.029) | | | | (.034) |
| Average growth rate | - | .286† | - | - | .244† | - | .224* | - | - | .404† |
| | | (.149) | | | (.131) | | (.195) | | | (.169) |
| Average openness growth rate | | | .129 | - | .079 | - | | .123 | - | -.005 |
| | | | (.109) | | (.108) | | | (.132) | | (.118) |
| Average inflation rate | - | - | - | -.011 | -.014 | - | - | - | -037** | -050** |
| | | | | (.019) | (.021) | | | | (.010) | (.012) |
| Constant | -.035 | -.326** | -.249** | -.255** | -.127 | -.178** | -.397** | -.350** | -.311** | -.238* |
| | (.055) | (.054) | (.030) | (.034) | (.073) | (.064) | (.059) | (.041) | (.035) | (.090) |
| Adjusted $R^2$ | .136 | .036 | .003 | -.005 | .146 | .052 | .015 | -.0003 | .082 | .199 |
| *n* | 73 | 73 | 70 | 74 | 69 | 65 | 64 | 62 | 65 | 61 |

Notes: The results of estimating the equations (5a) and (5b) are presented. Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors of (5a), with positive changes $\Delta\hat{u}^{+}_{i,v2,v1}$ as regressand. Panel B gives coefficient estimates and their heteroskedastic-consistent standard errors of (5b), with negative changes $\Delta\hat{u}^{-}_{i,v2,v1}$ as regressand. **, * and † indicate the statistical significance at the 1%, 5% and 10% levels, respectively. Entries in *n* row indicate numbers of observations. Due to data constraints, the numbers of observations vary across specifications

Table 5 Revision in Misalignment Estimates – A Combined Model

| | WDI revision | | PWT-WDI differential | |
|---|---|---|---|---|
| *Panel A:* $\Delta\hat{u}^{+}_{i,v2,v1}$ | | | | |
| Non-benchmark | .150* | .164** | -.067 | - |
| | (.067) | (.053) | (.082) | |
| Low data quality | .198** | .194** | -.031 | - |
| | (.069) | (.031) | (.062) | |
| Initial output level | -.004 | - | -.100* | -.074** |
| | (.037) | | (.043) | (.021) |
| Average growth rate | .215* | .197* | -.005 | - |
| | (.095) | (.084) | (.114) | |
| Average openness growth rate | -.069 | - | -.196 | -.166 |
| | (.053) | | (.158) | (.102) |
| Average inflation rate | -.140 | - | -.049 | .021 |
| | (.234) | | (.031) | (.015) |
| Constant | .024 | .016 | .104* | .111** |
| | (.026) | (.026) | (.047) | (.028) |
| Adjusted $R^2$ | .403 | .418 | .124 | .242 |
| *N* | 65 | 65 | 70 | 85 |
| *Panel B:* $\Delta\hat{u}^{-}_{i,v2,v1}$ | | | | |
| Non-benchmark | .107 | - | .061 | - |
| | (.073) | | (.172) | |
| Low data quality | -.065 | -.182** | -.188 | - |
| | (.073) | (.043) | (.128) | |
| Initial output level | .070$^{\dagger}$ | - | .072 | .053* |
| | (.041) | | (.047) | (.029) |
| Average growth rate | .335 | .398$^{\dagger}$ | .379 | .421* |
| | (.217) | (.229) | (.276) | (.170) |
| Average openness growth rate | .016 | .025 | -.293 | - |
| | (.135) | (.153) | (.182) | |
| Average inflation rate | -.066 | -.065 | -.018 | -.051** |
| | (.053) | (.055) | (.024) | (.012) |
| Constant | -.104 | -.153 | -.006 | -.277** |
| | (.072) | (.071) | (.125) | (.079) |
| Adjusted $R^2$ | .217 | .189 | .129 | .197 |
| *n* | 50 | 50 | 45 | 64 |

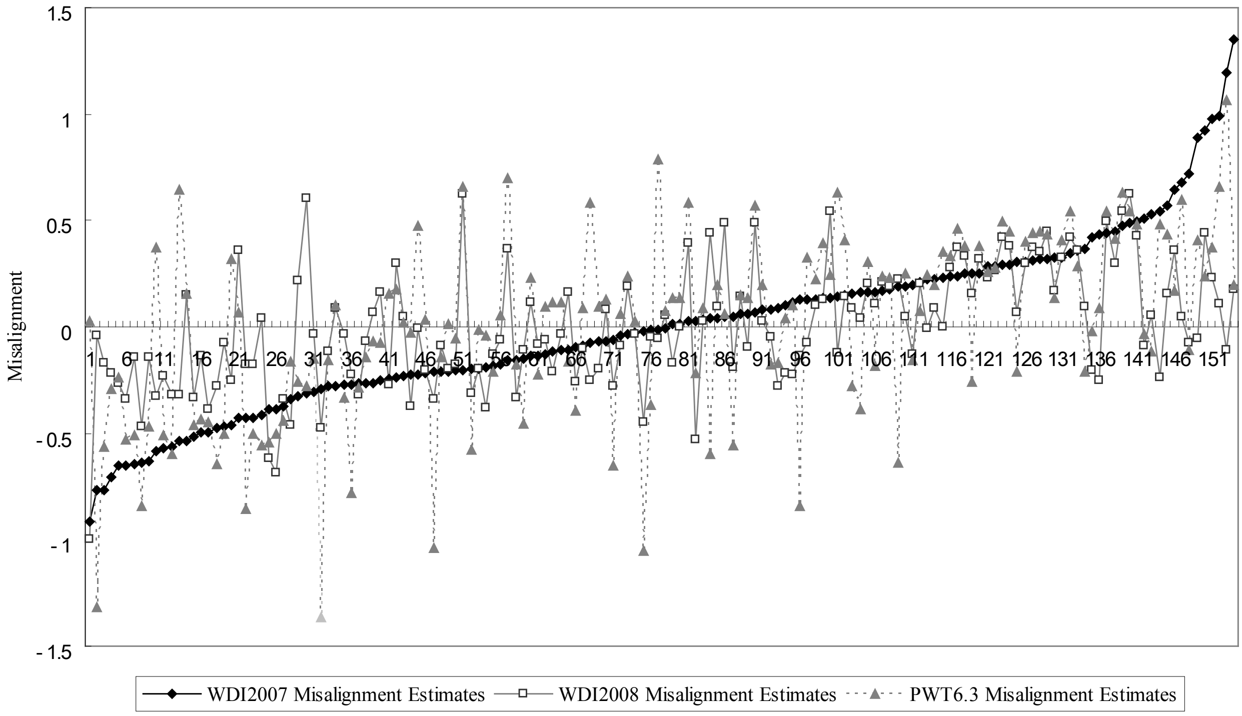
Notes: The results of estimating the equations (6a) and (6b) are presented. Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors for (6a), with positive changes $\Delta\hat{u}^{+}_{i,v2,v1}$ as regressand. Panel B gives coefficient estimates and their heteroskedastic-consistent standard errors for (6b), with negative changes $\Delta\hat{u}^{-}_{i,v2,v1}$ as regressand. **, * and $^{\dagger}$ indicate the statistical significance at the 1%, 5% and 10% levels, respectively. Entries in the *n* row indicate numbers of observations. Due to data constraints, the numbers of observations vary across specifications.

Table 6 Modified Penn Regression Estimation Results

| | *WDI* 2007 | *WDI* 2008 | *PWT*6.3 |
|---|---|---|---|
| *A. Estimation results* | | | |
| GDP per capita | .243** | .131** | .196** |
| | (.039) | (.017) | (.036) |
| Advanced*GDP per capita | .381* | .210 | .066 |
| | (.166) | (.151) | (.166) |
| Constant | -.398** | -.497** | -.562** |
| | (.086) | (.046) | (.088) |
| Advanced dummy | .643** | .648** | .707** |
| | (.107) | (.082) | (.112) |
| Adjusted $R^2$ | .598 | .713 | .576 |
| Number of observations | 154 | 154 | .154 |
| *B. Implied misalignment* (%) | | | |
| China | -52.93 | -6.33 | -37.31 |
| India | -53.88 | -22.05 | -47.27 |
| Brazil | 11.33 | 12.82 | 20.79 |
| Russia | 1.88 | -13.15 | 4.27 |
| *C. By participation status* | | | |
| Benchmark | 3.72 [25.15] | -2.11 [17.10] | .32 [30.66] |
| Non-benchmark | -14.19 [33.05] | 8.04 [20.30] | -1.23 [28.19] |

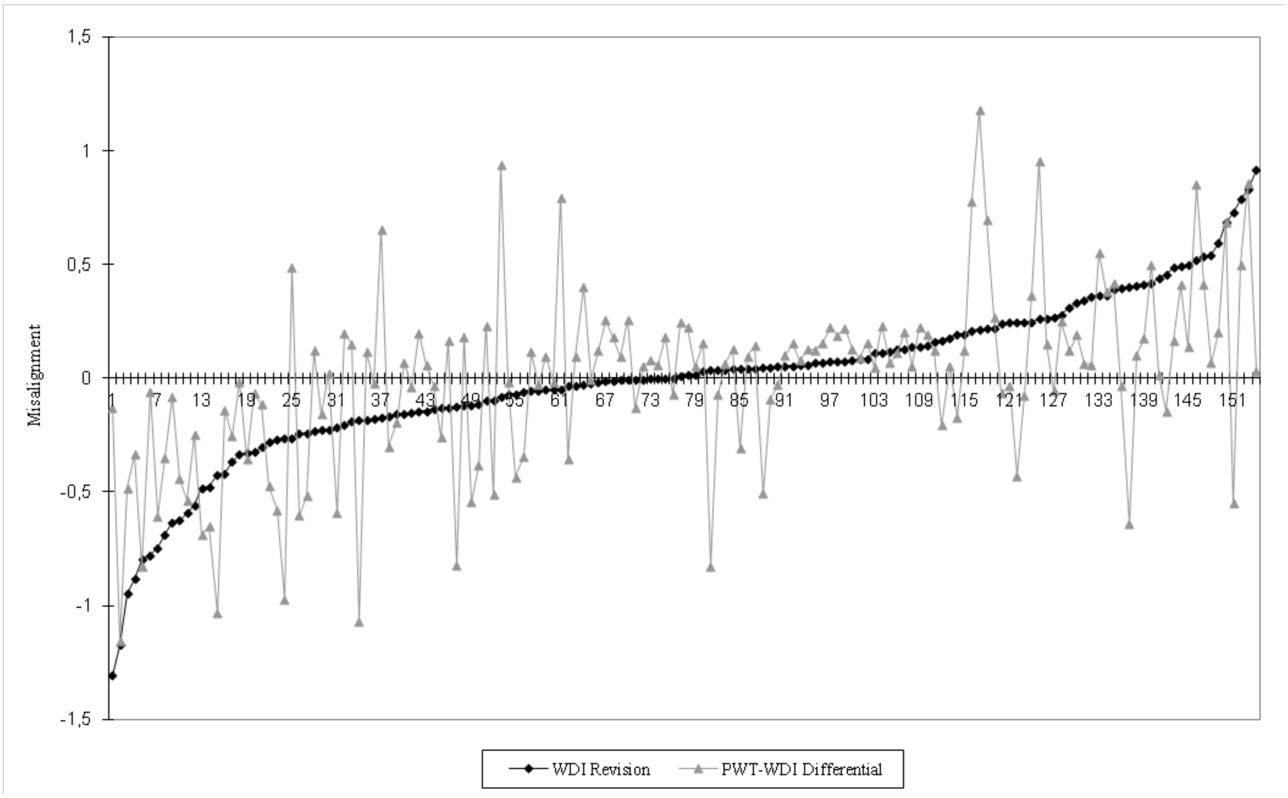
Notes: The results of estimating the modified Penn effect regression (7) in the text are presented. Panel A gives coefficient estimates and their heteroskedastic-consistent standard errors in parentheses. ** and * indicate statistical significance at the 1% and 5% levels, respectively. Panel B gives misalignment estimates of BRIC countries. Positive (negative) misalignment estimates indicate overvaluation (undervaluation). Panel C gives averages (and mean absolute values in brackets) of misalignment estimates of 1993 benchmark and non-benchmark countries. There are 122 benchmark and 32 non-benchmark countries.

Figure 1 Misalignment Estimates




Notes: The figure plots the misalignment estimates obtained by the Penn effect regression (1) in the main text using the WDI 2007, WDI 2008, and PWT 6.3 datasets.

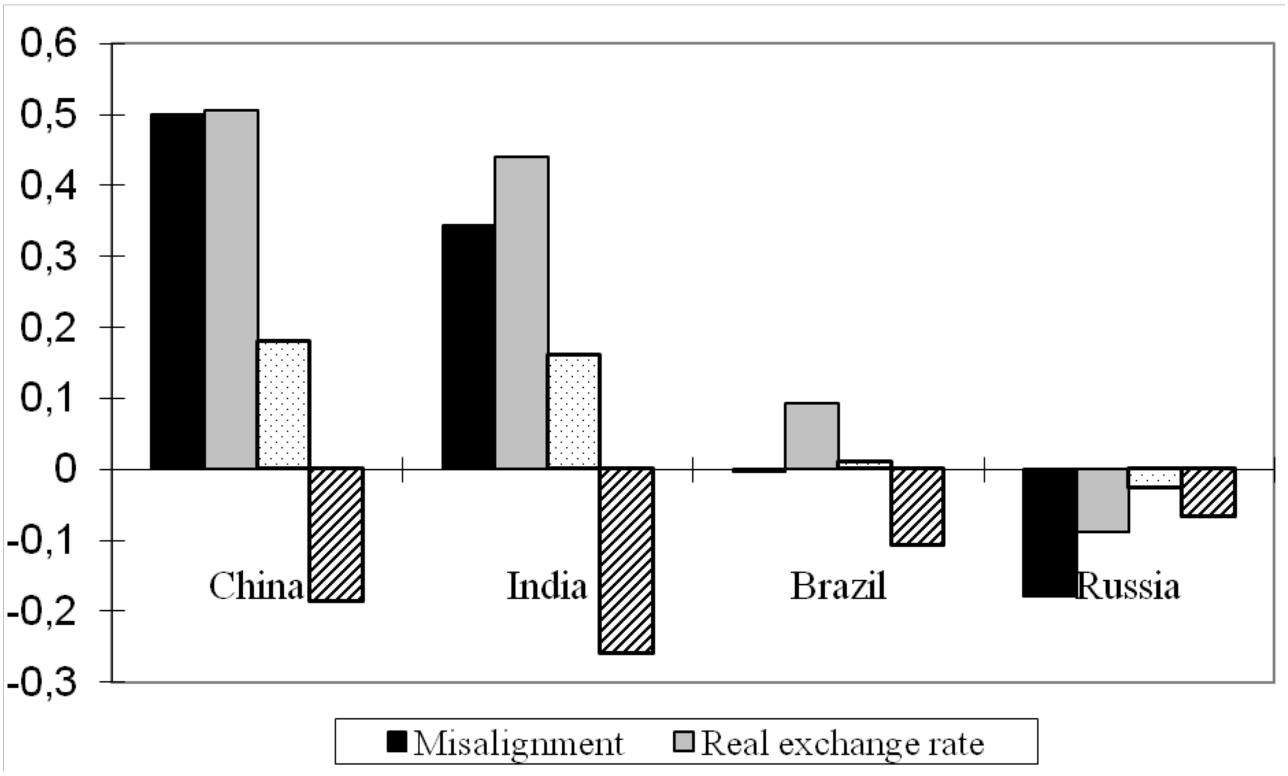
Figure 2 Differences in Misalignment Estimates




Notes: The figure plots the differences in misalignment estimates obtained by three alternative datasets: WDI 2007, WDI 2008 and PWT6.3. "WDI Revision" gives the differences between the WDI 2008 and WDI 2007 estimates. "PWT-WDI Differential" gives the differences between the PWT 6.3 and WDI 2007 estimates.

Figure 3 Decomposition of Misalignment Changes for BRIC Countries

A. WDI Revision

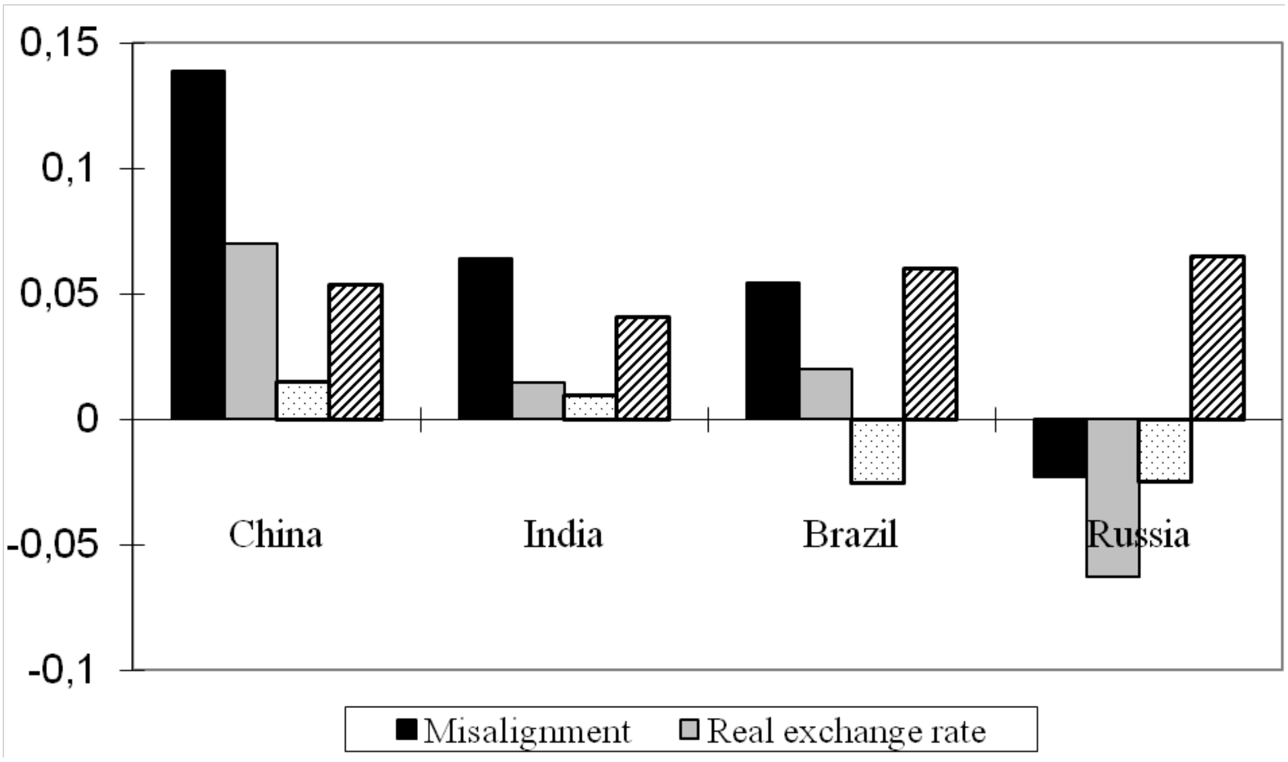



Notes: The change in misalignment estimates between WDI 2008 and WDI 2007 and their components are charted for BRIC countries. Decomposition is defined by (2) and (3) in the main text. Misalignment, Real exchange rate, Income, and Penn effect respectively correspond to

$\Delta\hat{u}_{i,v2,v1}$, $\Delta r_{i,v2,v1}$, $-[(\hat{\beta}_{0,v1}+\hat{\beta}_{1,v1}y_{i,v2})-(\hat{\beta}_{0,v1}+\hat{\beta}_{1,v1}y_{i,v1})]$, and

$-[(\hat{\beta}_{0,v2}+\hat{\beta}_{1,v2}y_{i,v2})-(\hat{\beta}_{0,v1}+\hat{\beta}_{1,v1}y_{i,v2})]$ in those equations.

B. PWT-WDI Differential



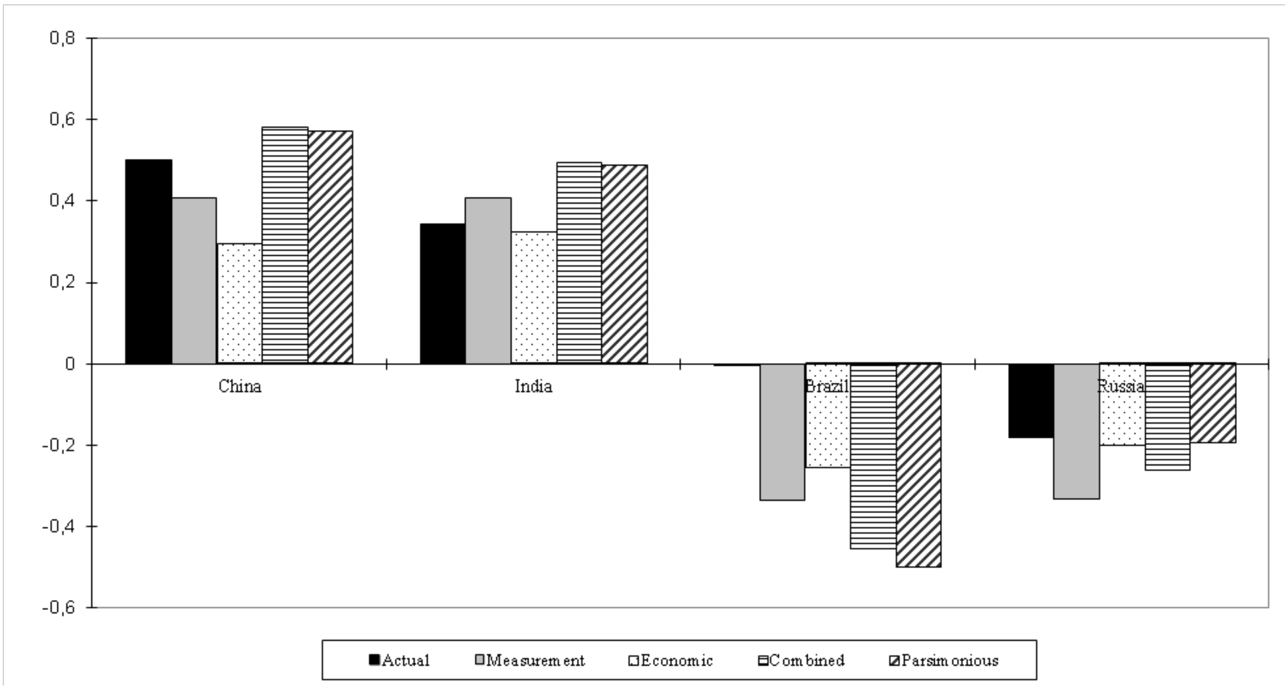

Notes: The change in misalignment estimates between WDI 2008 and PWT6.3 and their components are charted for BRIC countries. Decomposition is defined by (2) and (3) in the main text. Misalignment, Real exchange rate, Income, and Penn effect respectively correspond to

$\Delta\hat{u}_{i,v2,v1}$, $\Delta r_{i,v2,v1}$, -[ $(\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1} y_{i,v2})$ - $(\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1} y_{i,v1})$ ], and

-[ $(\hat{\beta}_{0,v2} + \hat{\beta}_{1,v2} y_{i,v2})$ - $(\hat{\beta}_{0,v1} + \hat{\beta}_{1,v1} y_{i,v2})$ ] in those equations.

Figure 4 Actual and Predicted Misalignment Changes for BRIC Countries

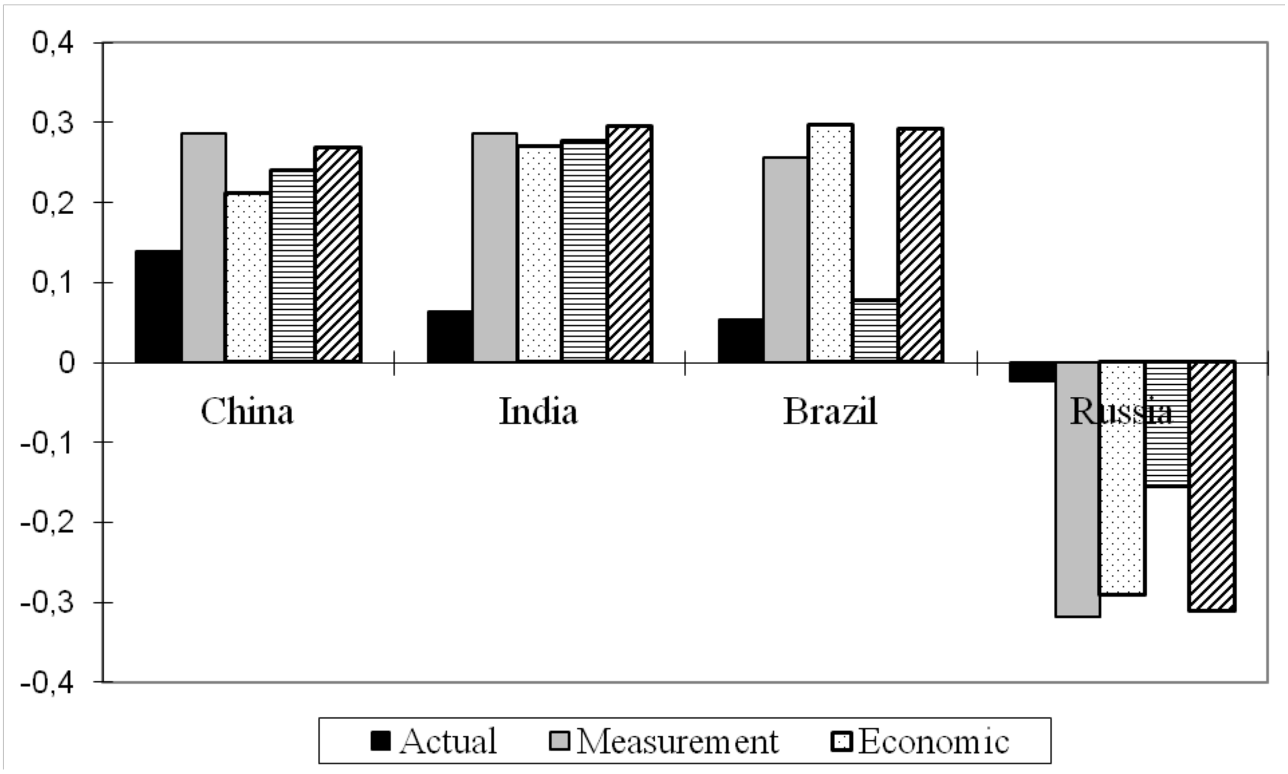
A. WDI revision




Notes: The actual and predicted misalignment changes between WDI 2008 and WDI 2007 are charted for BRIC countries.

Measurement, Economic, and Combined, respectively, denote changes in misalignment predicted by (4a) and (4b), (5a) and (5b), and (6a) and (6b) in the main text. Parsimonious indicates those predicted by parsimonious specifications of combined model given in Table 5. While the data quality information for Russia is unavailable, we assume that the country has a similar rating to those of other BRIC countries and assign $Q_i = 1$ for the purpose of the prediction exercise.

B. PWT-WDI differential




Notes: The actual and predicted misalignment changes between WDI 2008 and PWT6.3 are charted for BRIC countries.

Measurement, Economic, and Combined respectively denote changes in misalignment predicted by (4a) and (4b), (5a) and (5b), and (6a) and (6b) in the main text. Parsimonious indicates those predicted by parsimonious specifications of combined model given in Table 5. While the data quality information for Russia is unavailable, we assume that the country has a similar rating to those of other BRIC countries and assign $Q_i = 1$ for the purpose of the prediction exercise.

# Earlier BOFIT Discussion Papers

For a complete list of Discussion Papers published by BOFIT, see www.bof.fi/bofit

2011

No 1 Aaron Mehrotra and Jenni Pääkkönen: Comparing China's GDP statistics with coincident indicators
No 2 Marco Lo Duca and Tuomas Peltonen: Macro-financial vulnerabilities and future financial stress - Assessing systemic risks and predicting systemic events
No 3 Sabine Herrmann and Dubravko Mihaljek: The determinants of cross-border bank flows to emerging markets: New empirical evidence on the spread of financial crises
No 4 Rajeev K. Goel and Aaron Mehrotra: Financial settlement modes and corruption: Evidence from developed nations
No 5 Aaron Mehrotra, Riikka Nuutilainen and Jenni Pääkkönen: Changing economic structures and impacts of shocks - evidence from a DSGE model for China
No 6 Christophe J. Godlewski, Rima Turk-Ariss and Laurent Weill Do markets perceive sukuk and conventional bonds as different financing instruments?
No 7 Petr Jakubik: Households' response to economic crisis
No 8 Wing Thye Woo: China's economic growth engine: The likely types of hardware failure, software failure and power supply failure
No 9 Juan Carlos and Carmen Broto: Flexible inflation targets, forex interventions and exchange rate volatility in emerging countries
No 10 Andrei Yakovlev: State-business relations in Russia in the 2000s: From the capture model to a variety of exchange models?
No 11 Olena Havrylchyk: The effect of foreign bank presence on firm entry and exit in transition economies
No 12 Jesús Crespo Cuaresma, Markus Eller and Aaron Mehrotra: The Economic transmission of fiscal policy shocks from Western to Eastern Europe
No 13 Yu-Fu Chen, Michael Funke and Aaron Mehrotra: What drives urban consumption in mainland China? The role of property price dynamics
No 14 Mikael Mattlin and Matti Nojonen: Conditionality in Chinese bilateral lending
No 15 John Knight and Wei Wang: China's macroeconomic imbalances: causes and consequences
No 16 Gregory C Chow, Changjiang Liu and Linlin Niu: Co-movements of Shanghai and New York stock prices by time-varying regressions
No 17 Yanbing Zhang, Xiuping Hua, Liang Zhao: Monetary policy and housing prices; a case study of Chinese experience in 1999-2010
No 18 Peter Sarlin, Tuomas A. Peltonen: Mapping the state of financial stability
No 19 Zhichao Zhang, Nan Shi, Xiaoli Zhang: China's New exchange rate regime, optimal basket currency and currency diversification
No 20 Elena B. Deryugina, Alexey A. Ponomarenko: Identifying structural shocks behind loan supply fluctuations in Russia
No 21 Dong He and Honglin Wang: Dual-track interest rates and the conduct of monetary policy in China
No 22 Xinhua He, Duo Qin and Yimeng Liu: Exchange rate misalignments: A comparison of China today against recent historical experiences of Japan, Germany, Singapore and Taiwan
No 23 Vladimir Mau: The role of state and creation of a market economy in Russia
No 24 Elena Fedorova: Transfer of financial risk in emerging eastern European stock markets: A sectoral perspective
No25 Yin-Wong Cheung, Eiji Fujii: Exchange Rate Misalignment Estimates – Sources of Differences

Bank of Finland
BOFIT – Institute for Economies in Transition
PO Box 160
FIN-00101 Helsinki

☎ + 358 10 831 2268
bofit@bof.fi
http://www.bof.fi/bofit